The X-31 stands air combat on its tail

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Above the Pharaohs

Ultralights tackle the Egyptian desert

Flight without wings: the lifting bodies

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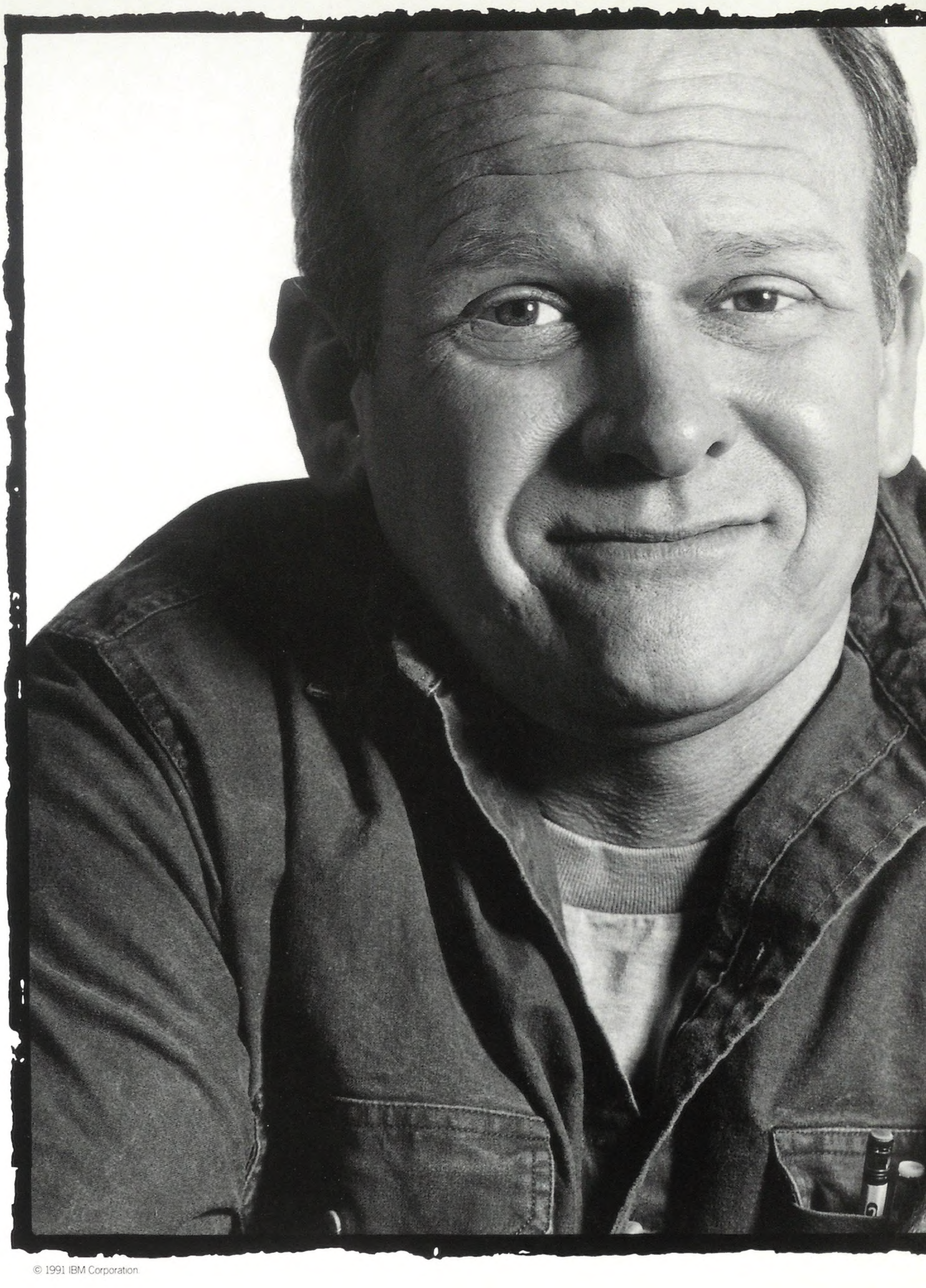

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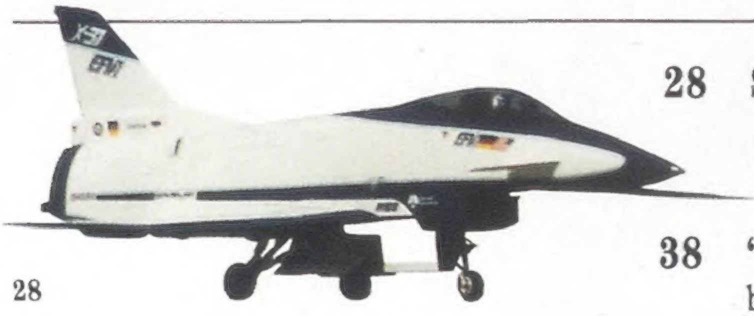
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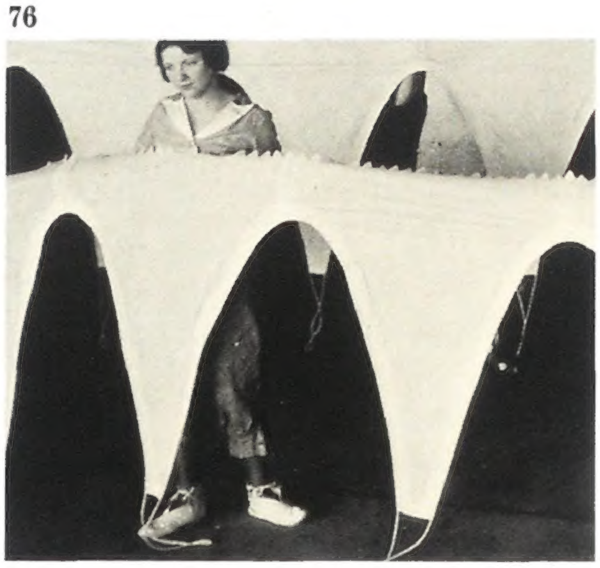

Departments

Cover: Simon Chaput's camera provided an ultralight's view of the land of the pharaohs.

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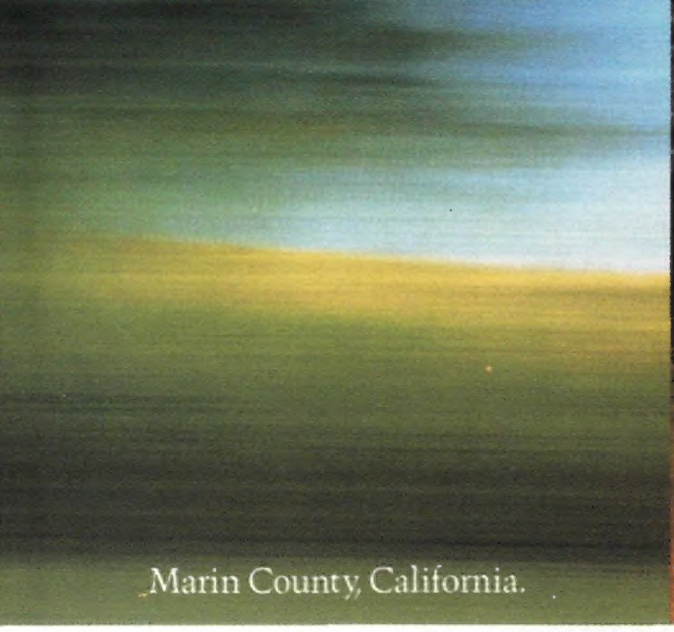

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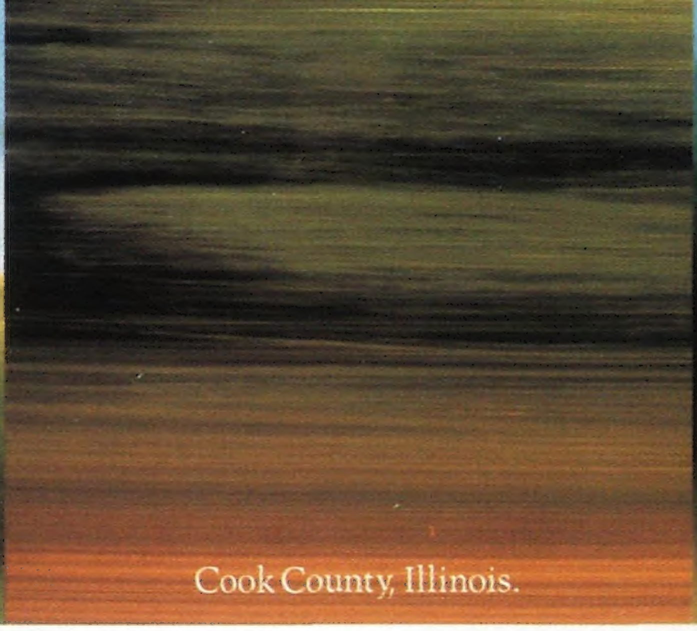
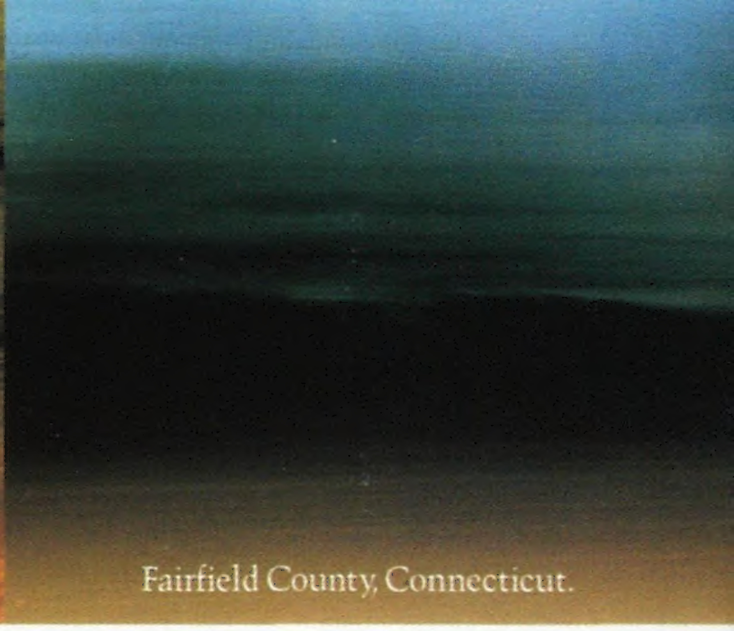


Cook County, Illinois.



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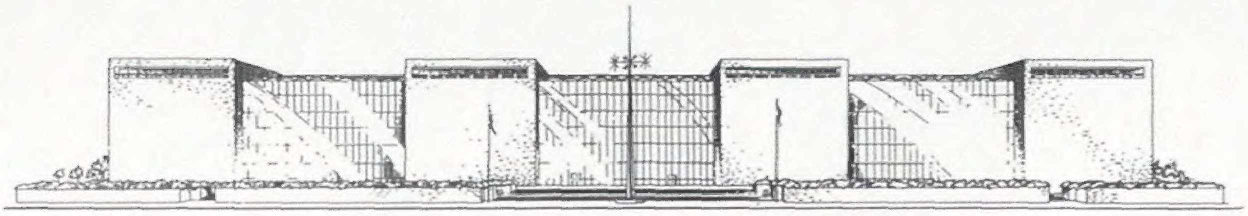

Truth in Labeling

Four years ago, just before joining the National Air and Space Museum, I found myself at a fine museum in London, where I came across a V-1 missile from World War II. A surprisingly genteel label made no mention of these missiles' being dropped on London during the war, but I marked that up to British reluctance to complain.

Some days later I was visiting Munich's Deutsches Museum, where a V-2 rocket label in contrast clearly stated that 7,000 people had been killed when these rockets were launched against Allied cities.

I mentioned the difference to my German host curator and he nodded matter-of-factly. But a minute or so later he looked at me and said, "Actually this label is new. We used to say nothing about casualties. And then people began writing in saying, 'What do you mean by displaying this missile without also describing the casualties inflicted?' "

When I started to work at the National Air and Space Museum some weeks later, I was naturally interested in comparing how the Museum had chosen to handle the issue. The label that was there told how the V-2 was the first really effective rocket to be used in war, and how it had contributed to early space science during the post-war years, when Americans had used captured V-2s to probe the upper atmosphere. No mention at all of war casualties.

Coincidentally, early in 1989, David DeVorkin, curator of space history, suggested that we work toward a more explicit exhibit around the V-2, which opened late in 1990. It shows a picture of the young Wernher von Braun briefing German officers at the height of his successes in wartime Germany. It tells of forced labor, with many prisoners literally worked to death, building these rockets in subterranean factories. There is a picture of a laborer, still in prisoner uniform, showing Allied soldiers a stockpile of V-2 parts. And we see the extensive damage done by a V-2 dropped on a populated square in Antwerp, where a fatally wounded man lies in the foreground.

A review of this exhibit in the *Washington Post* begins with the words, "Truth in labeling has finally come to the Smithsonian...." It praises the Museum for not mincing words, and for trying to tell the story with some sense of balance.

Of course it is always nice to be praised, but we also know that for everyone who appreciates our approach, there will be many who disagree. Some visitors feel we should be showing only the bright side of aviation and spaceflight, and nothing on the debit side. Others understandably worry about the children who love to come to the Museum but might be frightened by pictures of death and destruction.

There are other problems as well. Nowadays, all the Museum's major new exhibitions are funded through industrial or private sponsorship. We depend on generous donors who are willing to help the Museum, in exchange for not much more than public acknowledgment of their support. In this way we are putting together a new exhibit on the aerial combat of World War I, which will complement our longstanding exhibition of the fighter war in World War II.

Recently, we began to plan for an exhibition on the air war in Vietnam, and we quickly learned that corporate support was not likely to be found. Corporations, understandably, want to be associated with popular, upbeat events, and Vietnam was not one of those. We are now approaching philanthropic foundations to see whether funding might be forthcoming there. We hope to persevere, but it may take a lot of persistence.

The Museum and *Air & Space/Smithsonian* share a concern for telling stories straight and pulling no punches. We do that because we want our visitors and readers to trust what we say. And the only way to gain that trust is to portray events the way they actually happened—or at least get as close to that truth as we can.

That's never easy, nor is the straight message always nice.

—Martin Harwit is the director of the National Air and Space Museum.

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Letters

Datdatdatdat

Reading "The Joy of Rivets" by O.H. Billmann (February/March 1991) brought an old memory to mind. As a young man waiting to be called to active duty in 1943, I worked for a short time at Grumman Aircraft in Bethpage, Long Island. I remember that all the "Rosie the Riveters" and their male counterparts would be hard at work *dat-dat-dat-dat*-ing long before the whistle blew to start the morning shift. They built F6Fs and TBFs to the sound of "Elmer's Tune."

William F. Scheller
Pensacola, Florida

Slots and Slats

Martin Caidin's letter defining the difference between slots and slats (December 1990/January 1991) contradicts my education with the Royal Air Force. I checked my ancient notes on the de Havilland Tiger Moth, and there on the drawing that every student had to master before being allowed into the cockpit was the slot control, which locked the movable air guides during taxiing and takeoff. A severe wigging was given to the errant student whose instructor detected the rattling of these appendages while still on the ground. Perhaps the terminology was different in Europe.

John Brierley
Port Credit, Ontario, Canada

Sonic Snaps

"The Sonic Boom" sidebar of "Mach 1: Assaulting the Barrier" (December 1990/January 1991) makes the surprising statement that "supersonic bullets and artillery shells aren't heavy enough to create the phenomenon." My experience indicates otherwise. Perhaps supersonic projectiles create more of a snap or crack than a low-frequency boom. U.S. Army training manuals have long described the technique of using the "crack-thump" sound to determine the direction of hostile fire. The snapping sound of a passing

"You'll be happy to know your luggage set a new round-the-world speed record."

A Test Pilot Remembered

Having been a participant during the development of the North American Aviation F-100 Super Sabre, I decided to write after reading "Mach 1: Assaulting the Barrier" (December 1990/January 1991) with the hope of further enlightening your readers on "the North American factory test pilot who'd okayed the airplane [the F-100] in the first place." George Welch was the factory test pilot who died in a test of the F-100, but he was so much more to all of us here at NAA. We considered him a folk hero. In addition to being NAA's chief test pilot, Welch was one of only two U.S. pilots who managed to shoot down Japanese aircraft during the attack on Pearl Harbor.

If you saw the movie *Tora! Tora! Tora!* you may recall the scene in which two U.S. Army Air Corps P-40s got airborne and shot down a few of the Pearl Harbor attackers on that grim morning. One of those lads was Welch.

My tenure at NAA lasted from 1946 to 1955. When I arrived, the camouflage nets were still in place, drawn across the street even over to the Douglas plant. One could not see either plant while walking at ground level. Instead one saw a typical residential scene with streets, trees, and houses. But if one looked up at the camouflage net while walking along the street, all that could be seen were panels of crazy shapes and colors.

Emotionally and economically, I suppose the war had never ended. At that time we were wary of the threat of a ground-level Soviet air strike. Morale-building vaudeville troupes still appeared each Thursday at lunch break to entertain the factory workers. The wartime mindset had not ebbed, even two years beyond VJ Day.

During my stay at NAA, Welch made many miraculous saves in the initial flight testing of our early jets. Among these was the nearly disastrous first flight of the XP-86. The main landing gear jammed, but Welch calmly made a pass at low speed and bounced the other wheel soundly against the Muroc runway a few times. The violence of this subtle maneuver produced just the right amount of wing deflection to "uncork" the jammed gear. So George Welch earned his pay that day as well as on many other equally thrilling occasions.

As for the statement that Welch had "okayed the airplane in the first place," Welch was not the only Joe who okayed it. There was a lot of NAA and Air Force infighting going on. Chief of engineering Ray Rice and aerodynamics chief Ed Horkey had a few donnybrooks concerning the need for more lateral stability. The aero-Joes wanted larger vertical and dorsal fins. But drag was a big bogie in this brawl, so Rice won. (Not a bit surprising, since he was the boss.) Welch would never have griped about loss of stability during shallow supersonic pullouts unless he had actually experienced it himself.

Concern about drag is best illustrated by the fact that all of the F-100 empennage airfoil sections had three and a half percent thickness or a fineness ratio equaling 28.570. As a structures engineer I recognized a fresh challenge in resisting our tail loadings with a maximum thickness of about one handbreath. Nevertheless, most of the structural sizes were dictated not by strength but by need for stiffness. The thin surfaces were a flutter engineer's nightmare. When we tested on Colonel John Stapp's supersonic sled at Muroc, the tails virtually exploded. Eventually we managed to design a thick-skinned but light-as-possible winner. It was heavy, but it lived.

The Chance-Vought F8U Corsair was in test at Edwards Air Force Base concurrently with the F-100. We were told that the Edwards flight line mechanics "blew their circuits" when they saw our razor-thin tails after encountering five or six percent tail thickness on the Corsair. Still, I must sheepishly concede that the F8U *was* the faster airplane. After our struggles with the three and a half percent thin all-movable tails, we heard that Lockheed's F-104 had five percent thickness in its wing. Nobody at North American believed this.

When the F-100's lateral stability problem surfaced so malevolently that non-NAA pilots started "wringing it out" at Mach 1 plus, several fatal mishaps occurred. So NAA and the Air Force decided to let Welch handle it. Flying a fully instrumented and telemetered aircraft, Welch repeated the shallow pullout maneuver that had been mysteriously killing F-100 pilots. Welch's F-100 went into a 15-degree yaw at about Mach 1.15 during the pullup and the airplane disintegrated.

Welch's parachute opened automatically after the rupture forces ejected him, still fastened to his seat. He died in the ambulance soon afterward. A brave and good man was lost at age 32.

As a stress analysis engineer in the control surfaces group, I participated in designing the modification kit that enlarged the F-100 vertical stabilizer. Fin area was increased for greater lateral stability. The resulting design provided the desired stability while simultaneously giving the F-100 its now familiar rakish appearance. But we couldn't have made this modification without the data obtained from Welch's fatal flight.

George Welch was also something of a character. In the late 1940s and early 50s, he drove an English sportscar convertible while wearing sunglasses, scarf, and a navy blue beret. To complete his outfit, he wore loud checkered slacks and a leather jacket. A real trendsetter, he wore his hair down to his shoulders.

Because of his somewhat outlandish image, many thought Welch some kind of a Hollywood freak, giving him the nickname "Wheaties." This came from a rumor that he was an heir to the fortune of a family active in the food industry. But the Hollywood image was just Welch's way of drawing attention away from the real man, who was a very serious engineer and test pilot. We all missed him and grieved for weeks after he died.

Robert F. Reiland
Palm Beach Gardens, Florida

supersonic bullet alerts one to the occurrence of fire, and one then listens for the sound of the muzzle blast arriving at mere sonic speed to figure out the direction from which fire comes. This past October, I tended targets in the pits at the Iowa High Power Rifle State Championships, and the crack-thump effect was much in evidence. Snaps from the shock waves of hundreds of bullets were too obvious to ignore as they passed over our heads. The dull thumps of each muzzle blast came along up to a second later. A bullet's shock wave can hardly compare with that from a supersonic aircraft, but it does exist.

Dean C. Spraggins
Omaha, Nebraska

Editors' reply: While you are correct that projectiles create shock waves, the author is

also correct in stating that these shock waves are not large enough to be described as sonic booms.

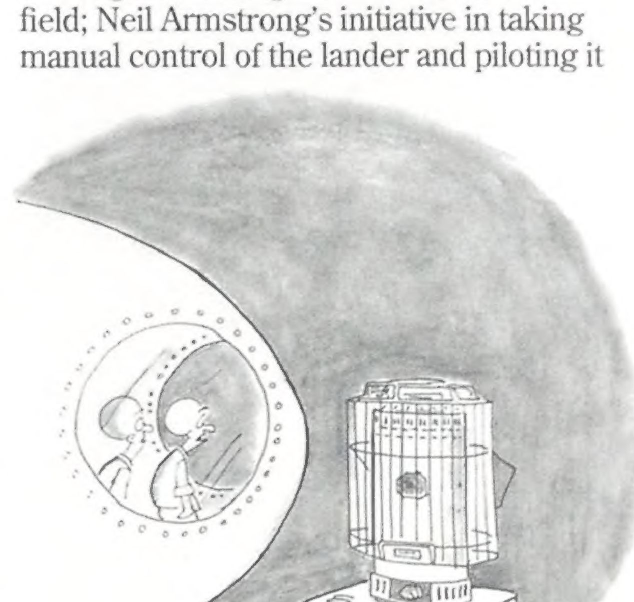
The Expanding Role of Blimps

I found John Grossmann's "The Blimp Bowl" (February/March 1991) a fascinating look at airships as television platforms for sporting events. However, the article reinforces the misconception that this is the only role for airships. Let us not forget that during World War II not a single ship was lost to enemy submarines while under the protection of an airship. More recently, Goodyear's *Columbia* served as a research platform for scientists from the Jet Propulsion Laboratory. Because airships have highly stable flight characteristics, the Naval Research Laboratory is also considering their use. And in 1993 the Navy will once again be flying an airship, a version of the AWACS that will be able to operate with the fleet for months.

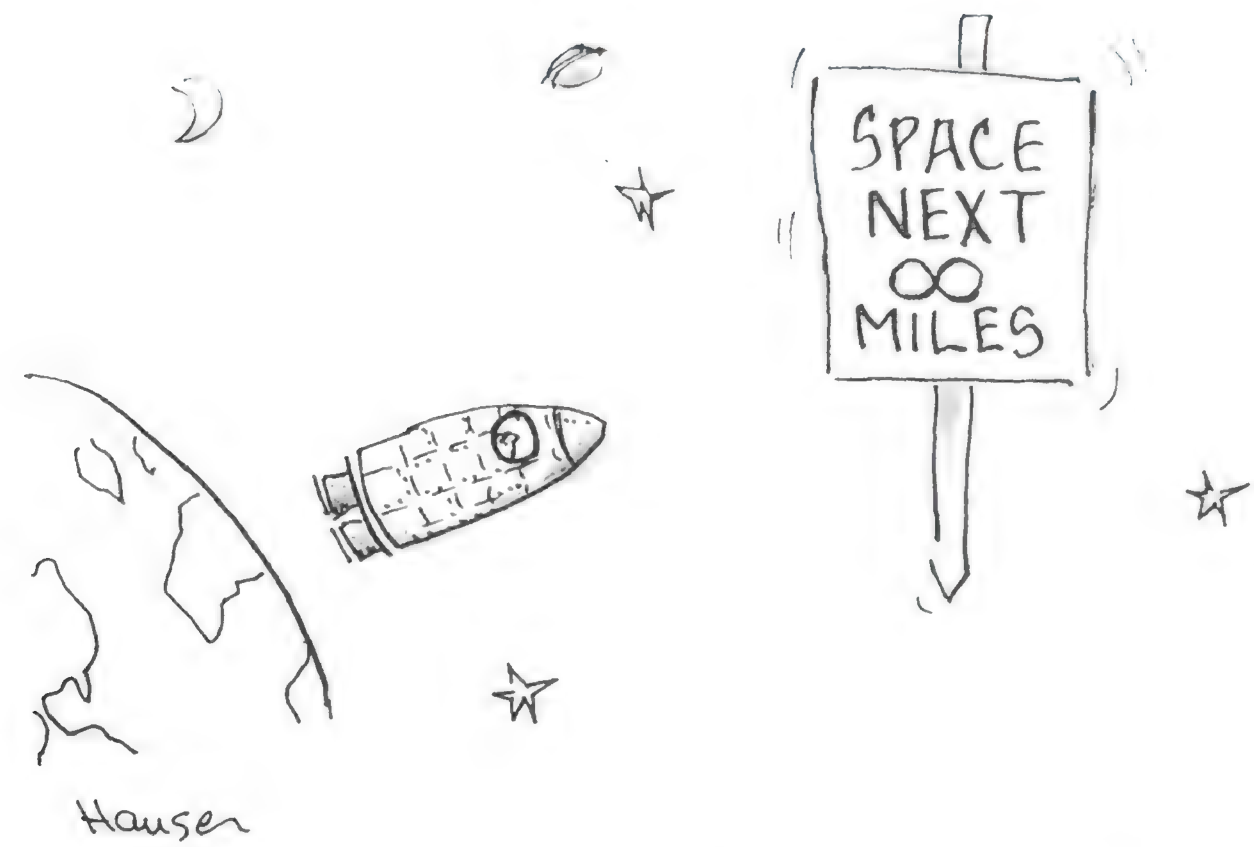
Karl C. Kalbaugh
Reston, Virginia

Robots vs. Humans

It seems to me that the essential point of Stephen P. Maran's letter ("Science vs. Exploration," February/March 1991) was not that American men got to the moon before Soviet robots but that robots, of whatever nationality, are not necessarily superior. Maran mentioned the repeated crashes of robotic vehicles; had the Apollo 11 lander been a robotic vehicle, it too probably would have crashed. Recall that the original landing site was a boulder field; Neil Armstrong's initiative in taking manual control of the lander and piloting it



"It's a space heater."



to a safer site saved the mission from disaster. Until the day comes when robots have the initiative and judgment to respond to the unexpected—in other words, when they are able to think on their metaphorical feet—there will be a need for humans in the exploration of space.

John W. Floars
Woodbridge, Virginia

Sharkophobia

"Carrot and Shtick" (Soundings, February/March 1991) stated that shark mouth markings were not used as nose art before World War II. Not so. The shark mouth motif was rather widely used by at least three or four of the air services engaged in World War I, starting in 1916 at the latest. It seems that the menacing appearance of the toothy grin was in use from the very early days of man's attempt to dominate the sky and instill fear in his opponent.

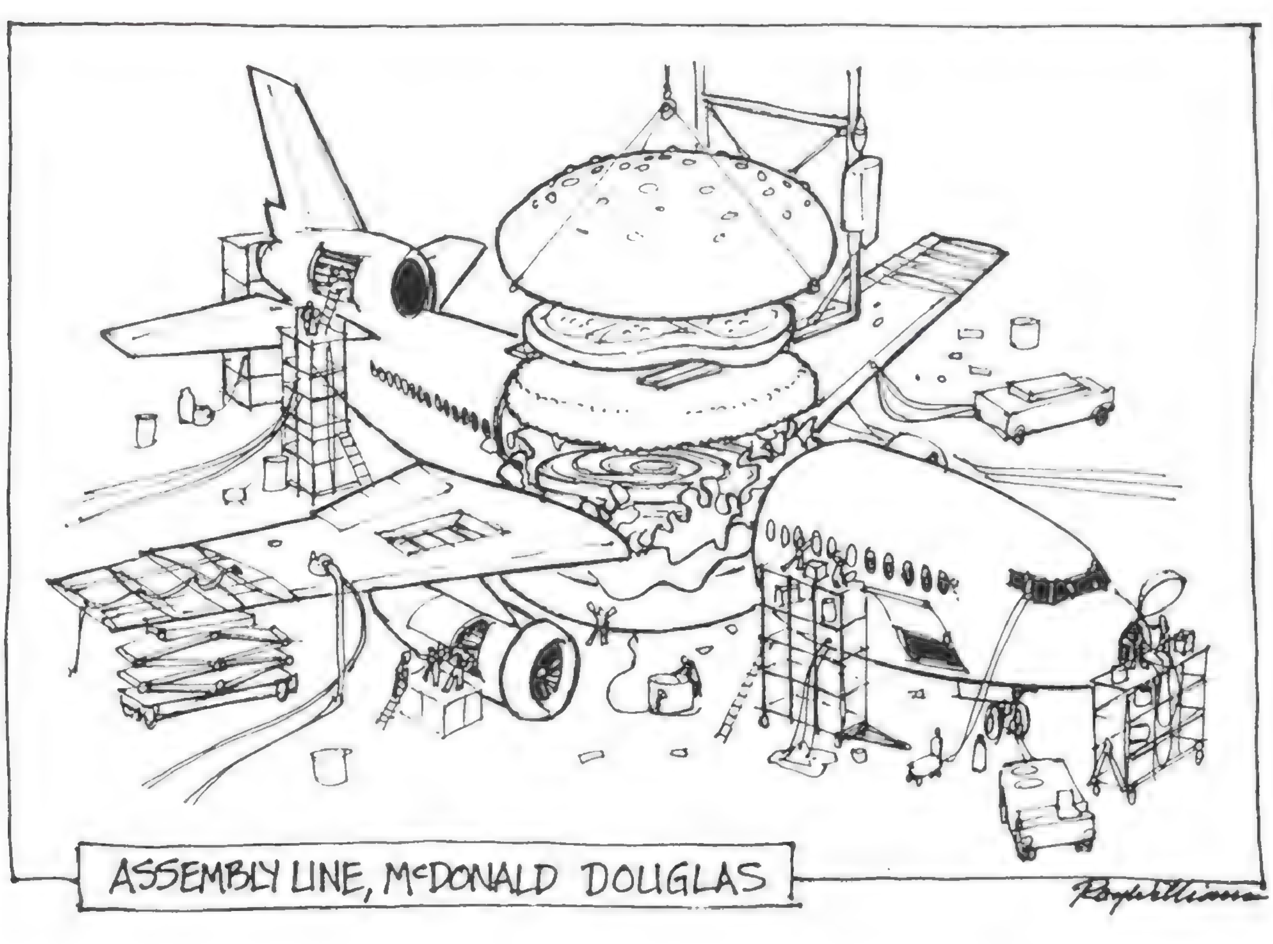
Robert L. Horton
Moline, Illinois

Dragged Into Service

Steven R. Reinhardt's letter citing Navy drag races between cars and aircraft as an example of "fraud, waste, and abuse" (February/March 1991) left me almost speechless. Yes, the Navy probably will justify it as recruiting. When I was considering a career in the Navy, I read an article in a car magazine about a 1975 race

between Tom McEwen and an F-14 . One year later I was in the Navy. I've accumulated over 3,000 flight hours (2,400 in the F-14) and over 14 years of active and reserve flying to date. Not bad recruiting on the Navy's part, I'd say. As for his claim that the Air Force is short on cash, I guess Reinhardt doesn't remember that last summer Congress asked the Air Force to explain spending $10 million to install fireplaces in selected officers' quarters.

Lieutenant Commander Ted Jacobson
U.S. Naval Reserve
San Diego, California



Stop Stifling Inventors

Shame on Beech Aircraft for trying to make John Roncz ("Wing Man," December 1990/January 1991) into a manager of its aerodynamic divisions. Has Beech management learned nothing in its long history of developing airplanes? People with technical talent should be given every opportunity to develop that talent without being moved into management. That is killing the goose that lays the golden eggs. Since I joined the F-102 team at Convair, I have observed this practice for the last five decades. Give guys like Burt Rutan and John Roncz fiscal support and let them invent the things that the flying world needs.

Earl R. Hinz
Honolulu, Hawaii

Carrier-Qualified

Patricia Trenner's account of an A-12 being placed aboard the New York City-based aircraft carrier *Intrepid* was great ("A Manhattan Project," Soundings, February/March 1991). However, as a longtime Army and National Guard helicopter pilot, I politely contest the following statement: "It's been a long time since anything landed on the *Intrepid*."

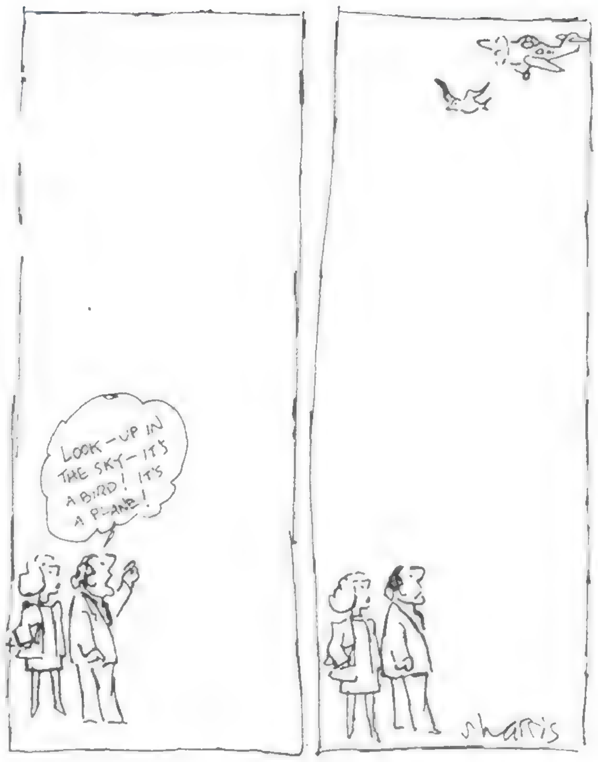
Donald Francis, who was director of flight operations for the Sea-Air-Space Museum, occasionally requested that helicopters from the New Jersey Army National Guard land on the *Intrepid*'s helipad. I proudly display my "carrier-qualified" certificate to friends, who get confused and say, "Oh, I thought you were in the Army!"

Richard F. Andrews
West Trenton, New Jersey

Corrections

Is it possible that author Stephan Wilkinson ("Mach 1: Assaulting the Barrier," December 1990/January 1991) could be wrong when he identifies the YP-38 piloted by Ralph Virden that lost its tail as being the same one that Lockheed modified to a raised- tail configuration almost a year later?

Kenneth W. Taylor
Burbank, California



Editors' reply: Stephan Wilkinson wasn't wrong; the editor who added that information was. Several readers have written to correct the statement that Ralph Virden was flying a YP-38 with a raised tail. Experts have disagreed on this point for some time, but those who say that the tail was raised on a later version make the more convincing case.

In "A Guide to NASA" (February/March 1991), a map of the California desert correctly locates the Hugh L. Dryden Flight Research Facility but labels it the Ames Research Center. Dryden is a unit of Ames, so the error is understandable but misleading.

Philip N. French
Camp Springs, Maryland

A typical launch fee is about $10 million per launch, not $10 million per pound, as stated in the February/March 1991 Viewport.

Due to a reporting error, "And In This Corner..." (Soundings, December 1990/January 1991) states that "the Air Force's last fighter, the F-15, entered service in 1975..." The F-15 is not the Air Force's last fighter, but it is the one that the Advanced Tactical Fighter will replace.

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(900) 258-2MIR or NOT 2MIR

A trip to the Soviet space station Mir, billed as "the ultimate adventure" for one ordinary but lucky American, has become the ultimate headache for two Texas entrepreneurs who offered a chance to win the trip for the price of a phone call.

Two months after David Mayer and James Davidson launched the unprecedented sweepstakes, the co-founders of Houston-based Space Travel Services were facing criminal charges and consumer fraud investigators were facing the tedious task of refunding an undetermined amount of money to thousands of aspiring cosmonauts who last winter dialed (900) 258-2MIR at $2.99 a call to enter the contest.

"The idea of sending Mr. John Q. Public on a spaceflight is wonderful," says Jean Hughes, a prosecutor handling the case. "But whether this is a free trip to space or a free trip to California, their method of offering it is against the law." Gambling promotion, the felony charge that sent the promoters to jail for the night of February 6, carries a sentence of 10 years in the state penitentiary and a $10,000 fine. Texas authorities have charged Space Travel with running an illegal lottery by selling chances on a prize for money; the company claims it's running a sweepstakes with no purchase required.

Space Travel Services had planned a yearlong contest pitting 12 randomly selected finalists in a drawing for the grand prize—one week aboard Mir or $1.5 million cash. The sweepstakes, launched December 17, raised eyebrows around the world. Tass, the official Soviet news agency, called the contest a hoax. Even Glavkosmos, the Soviet space agency, did not acknowledge the deal until Davidson and Mayer showed reporters a copy of their flight contract. Closer to home, would-be entrants quickly grew frustrated when they called the 900 number. Space Travel Services reported it had gotten more than 5,000 calls an hour—enough to overload the sweepstakes line—in the first two days of the contest.

A month earlier, Davidson and Mayer inked a multi-million-dollar deal for their flight through Space Commerce Corporation, a Houston firm that markets space products and services for the Soviets (see "Soviet Booster," February/March 1991). The pair would not disclose the exact price of the flight, but they said that Space Travel Services expected to keep more than half the phone call revenue from

"Carnations" and "Cabernet Sauvignon" are two of the Earthly delights portrayed by Steve Gildea in his exhibit "Things I Would Miss on the Way to Mars." Other works displayed at Boston's New England School of Art & Design last December depict dozens of books surrounding an astronaut drifting in space and two astronauts absorbed in an extravehicular chess game.

an expected several million entries.

Space Commerce vice president William Wirin blamed the initial mixup on poor communications with the Soviets, but that wasn't enough to convince Texas prosecutors that the deal was legitimate. They sought a grand jury indictment. "We told them to refund the money or we would seize it as gambling proceeds," says Hughes.

Davidson and Mayer weren't talking after their ordeal, but in a January interview they insisted they were operating within the law and had cleared contest plans with a Dallas lawyer. Wirin said the pair assured Space Commerce that the sweepstakes was legal. "I expect lawyers to act in a lawyer-like fashion, which is to have their facts and act on their facts," he says. "That's why it was a complete surprise the boys were arrested." Hughes says that Space Commerce will not be implicated in the alleged lottery scheme.

"They were looking at us just because we were big, we were really different, we were highly publicized, and the prize we were offering was a trip to space," said Mayer, Space Travel Services president and CEO. "We bent over backwards to make sure everything was straight," said Davidson, who has a marketing background and a master's degree in business administration.

On January 21 Mayer and Davidson said they had struck a deal with authorities that permitted them to keep taking calls by offering something tangible for the $2.99 charge—a newsletter that contains a contest entry blank—instead of directly offering a chance at the prize. Hughes confirms that the newsletter was discussed, but "that was not all of the agreement. There was still the issue of the funds," she says, referring to the money already collected from the phone calls. Officials say they aren't sure the money will ever be refunded because of the effort involved in contacting every caller.

While prosecutors prepared their case for a grand jury, Space Commerce was hunting for another buyer for the trip at a $12 million minimum. "We would like to see an average American go into space, because that's not an opportunity that will happen very often," Wirin says. "The seat can be used for any lawful purpose. Have you got a rich uncle?"

—Beth Dickey

The Big Bash Theory

For the past decade scientists have searched the globe for evidence that an asteroid or comet slammed into the earth, creating a kind of nuclear winter that killed

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off the dinosaurs and other species around 65 million years ago, at the Cretaceous-Tertiary (K-T) geological boundary. According to Alan Hildebrand of the planetary sciences department at the University of Arizona at Tucson, the impact may have occurred between North and South America—and he thinks he's close to finding the site.

"When you look at the K-T boundary layers around the world," Hildebrand says, "you see the 'fireball' layer, about a three-millimeter [.10-inch] layer rich in iridium and other trace elements associated with a space projectile. It's always the same thickness and therefore doesn't have any information on where the impact may be." But in southern North America and the Caribbean there are large concentrations of shock-formed minerals and deposits that resemble ejecta, suggesting that an impact crater exists somewhere in the region.

In 1988 Hildebrand found evidence of a possible impact site in the Colombian Basin, and north of it in Haiti, a K-T layer shows telltale signs of tektites and sizeable shocked quartz grains throughout the fireball layer. The thickest ejecta layer found in North America is about one inch; at the Haiti site it is nearly 20 inches.

The age of the 186-mile-wide structure in the Colombian Basin has not yet been determined. A more promising entry in the race to find the actual impact crater is a site in Mexico, a 112-mile structure buried beneath the town of Chicxulub on the northern Yucatan peninsula. "Impact craters have clear gravity [field] signatures," says Hildebrand. "Chicxulub has a spectacular signature, along with being circular, having two rings, and a central uplift peak." In addition, a 262-foot-thick ejecta-like deposit exists 31 miles from the edge of the crater.

"Now that we have a small area of the earth's surface to search," Hildebrand says, "we'll be able to establish that there was an impact, maybe find the crater, and even cut off the debate as to whether K-T species died out because of volcanism or impact cratering."

—Patricia Barnes-Svarney

Update

Balloonists Cross Pacific

Balloonist Per Lindstrand ("Twelve Miles Over Laredo," December 1988/January 1989) and Virgin Atlantic Airways chairman Richard Branson became the first to cross the Pacific Ocean in a hot-air balloon last January 17. The 6,700-mile trip from Japan to Canada took 48 hours.

The Airshow Must Go On

With the Pentagon busy rounding up troops and equipment in and around the Persian Gulf, airshow organizers back home have been struggling to fill the gaps left when their main attractions took off to fight. The Daytona Skyfest (April 20 and 21, Daytona Beach, Florida) would normally have up to 70 military aircraft on display, but two months before opening day producer Rick Grissom didn't know what he'd have to offer come showtime.

"It's a double-edged sword," he said. "The war has made it harder to get military participation. But by the same token there is heightened awareness on the part of the general public, and they want to come out and see the planes they've been seeing on TV every night."

The military is doing everything it can to accommodate some 380 airshows scheduled in 1991. With the exception of aerial demonstration teams like the Air Force Thunderbirds and Navy Blue Angels, airshow participation is incorporated into training missions. Airshows also give the defense department an opportunity to show the public where its tax dollars are going—though that may seem less important now that U.S. air power in action has been featured on the nightly news. But, says Lieutenant Colonel Brent Jones, aviation liaison for the defense department, "they still have lots of questions that they want to ask the pilots and other personnel. This gives us an opportunity to educate them."

Airshows also place military assets at risk. With the increased possibility of terrorist attacks, open houses at military bases could be canceled at any time. Civilian airshows counting on military participation may have to meet tighter security requirements, and event organizers will have to be prepared to deal with demonstrators. "The risk is on everyone's mind," says Jones. "We have to continually ask: Is it worth it?" Even so, he says, the Pentagon remains committed to public appearances and will participate whenever it can.

Meanwhile, Grissom has a show to put on. He has the Thunderbirds lined up for Saturday and a tribute to the men and women of Desert Storm for Sunday. "We hope the war will be over by then," he said, "but in any case, we won't know up to the last minute what we're going to have on display." Now that the war has ended, he can count on what he won't have. The C-130, C-141, and C-5 transports that people are used to seeing at airshows will be busy for months, bringing people home.

—Elaine de Man

Update

Museum Director, Sculptor, Early Flier Die

Don Madonna, director of Santa Monica's Museum of Flying (Soundings, August/September 1990), died last January 10 in the crash of a Folland Gnat. He was 53.

British artist Rowland Emett (In the Museum, December 1989/January 1990) died last November 13 in London at the age of 84.

Carl Hennicke (Collections, June/July 1990) died February 21 in a Long Island hospital at age 88.

Power Struggle

When the Soviets upstaged the cast of last January's Space Nuclear Power symposium in Albuquerque, New Mexico, U.S. scientists cheered them on. In a shrewd marketing ploy, the Soviets offered their Topaz 2 space nuclear power source for sale to the United States, where space nuclear power development is running on empty. Several research labs, including Los Alamos, Sandia, the University of New Mexico, and the Air Force, will pay about $10 million to buy a Topaz II and begin studying its metallurgical secrets.

U.S. scientists are largely unimpressed by the Topaz reactor technology but admit that production of flight-qualified hardware is a worthy achievement. NASA's Lewis Research Center says that tests of a sample of a single-crystal molybdenum-niobium alloy, a Soviet innovation, confirm its better resistance to the hostile environment in the reactor core.

The Soviets need cash. Nikolai Ponomarev-Stepnoi, a deputy director of the Kurchatov Institute of Atomic Energy, says the Soviet economy is in "critical" condition and science funds are decreasing. "They've been told to either make a profit or learn to make milking machines," says Richard Verga, head of key technologies for the Strategic Defense Initiative Office, adding that the Soviet institute's budget has been cut in half this year and will go to zero next year unless its technology brings in cash. As part of the deal, however, the Soviets insist that the technology be used only for "peaceful, commercial" purposes.

SDIO, NASA, the Air Force, and the Department of Energy are funding the purchase of the unfueled reactor and will provide another $100 million for a five-year study program. Though the Topaz in its present state is of little practical value to the SDI program, which has energy demands of 100 kilowatts of electricity for seven years, the Soviets say their reactor can boost its current output of six to 10 kilowatts up to 40 for five years. However, Verga's Topaz push is fueled by hopes that U.S. scientists will learn shortcuts for the development of a home-grown thermionic reactor.

Joseph R. Wetch, president of International Scientific Products in San Jose, California, set up the deal in a venture with a Soviet company to market Soviet reactor technology. He and his partners are looking for more than one sale. Wetch,

who bubbles with optimism, believes that once the Topaz gets a U.S. stamp of approval, he can sell a modifed version to the commercial satellite industry. "Nuclear power would make it possible to build a communications satellite with four times the capacity of today's models and double their useful lifetime in space," he says. "And once the labs start understanding the technology in these things, it will open some eyes."

The U.S. space nuclear power program has been plagued by fears of a launch or reentry accident and a lack of funding for the unpopular technology. The United States has been working on space nuclear power systems since the 1960s, but there is no flightworthy nuclear reactor in inventory. NASA relies on radioisotope thermoelectric generators when solar cells won't suffice, and critics say RTGs, powered by a plutonium isotope, are dangerous enough.

Topaz II predecessors have powered Soviet reconnaissance satellites since the 1970s. Most experts, including the 600 at the symposium, agree that any ambitious space program—a moon base, a Mars journey, or a missile defense system—is dead in the water without nuclear-powered utility and propulsion systems. "All the neat things man would like to do in space are either physically impossible or economic nonsense without space nuclear power," says Verga.

—Breck Henderson

Update

Space Station Robot Axed

The Flight Telerobotic Servicer under development at NASA's Goddard Space Flight Center ("Invasion of the Spacebots," February/March 1990) has succumbed to the space station budget cutback. In an effort to keep the robotics program viable, NASA will scale the FTS project down to development of the technology rather than the hardware.


LOCKHEED

Tomatoes That Kill

Investigators are studying the mysterious circumstances surrounding the recent slaying of several heads of lettuce. The crop was found dead in an experimental garden that may one day be used to grow vegetables in orbit. Unless scientists get to the root of the problem, the world's foremost green will be missing from salads tossed up in microgravity. "This is like an episode of 'Columbo,' " says Steven Schwartzkopf, a chief scientist at Lockheed Missiles & Space in Sunnyvale, California. "We know the tomatoes did it, but we have to figure out how."

Limited power supply and storage areas will limit astronauts' perishable stocks, so researchers are exploring farming methods for growing crops in orbit or on the moon. "It may not sound like much, but from a psychological perspective a fresh salad may be an important boost to crew morale," Schwartzkopf says.

Lockheed researchers are experimenting with hydroponics, tending salad crops in a rack that circulates liquid fertilizer around their roots. Plants grow faster in hydroponic solutions, and without soil, there's no worry about clumps of dirt floating around the cabin.

Schwartzkopf's lettuce thrived until tomatoes were planted beside it. "The tomatoes are either taking in too much of a nutrient the lettuce needs or putting out a toxic substance that is killing it," he says. "In either case, we're on to something here, and solving the mystery will make a good contribution to agriculture—on Earth and away from it."

Lockheed researchers are also trying to solve the case of the curly carrots. "The tops of the plants grew normally," says Schwartzkopf, "but the roots tended to curl up. Maybe it was the motion of the nutrient solution or maybe the lack of soil. Who knows—maybe in space, with little gravity, these things will grow into salad-ready carrot curls."

—Beth Dickey

What, No SpaceGum?

Every year collectors buy and sell millions of dollars worth of baseball cards. Edward White III is launching what he hopes to be an equally popular venture called SpaceShots, a series of cards based on the history of U.S. manned spaceflight. SpaceShots lacks a sheet of starchy pink gum, but it gives a lot of historical bang for the buck.

White, whose father died in the 1967 Apollo 1 capsule fire, created SpaceShots to honor Edward White II and stimulate youngsters' interest in the space program. The first series of 110 cards features most manned endeavors, from Alan Shepard's suborbital flight in 1961 through last year's launch of the Hubble telescope. Production was limited to 25,000 sets, priced at about $20 and sold in museum shops and NASA visitor centers. Future series will cover the Apollo program, a return to the moon or a Mars voyage, and the Soviet space program.

One-quarter of the proceeds will be donated to Cape Canaveral's Astronaut Memorial Foundation and the future Center for Space Education, which will train math and science teachers. White also plans a $150,000 scholarship program. Each series will contain 25 space trivia questions ("Who coined the phrase A-OK?" "What comic strip character 'investigated' the failure of the Ranger 6 TV cameras?"*) and a sheet for 100 answers that buyers of all four series can use as an entry form.

White, who was assisted by Buzz Aldrin and Bruce McCandless in editing the text on the back of each card, says the most difficult part of the SpaceShots endeavor was selecting the photographs. "We spent three or four months paring it down to the first 110," he says. "There's a wealth of material, especially in NASA's archives. They say they have more than five million photos."

(*Alan Shepard; Dick Tracy.)

—Kenneth J. Presti

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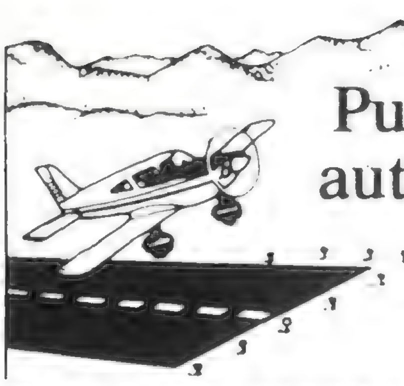

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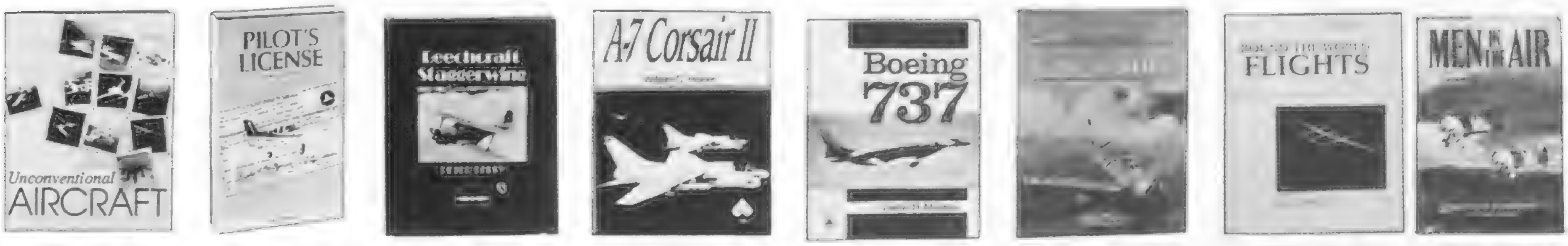

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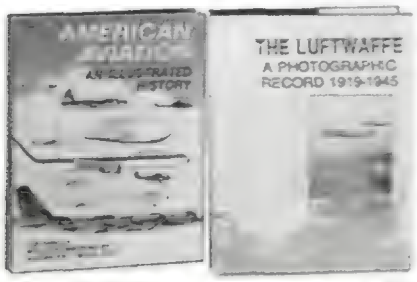

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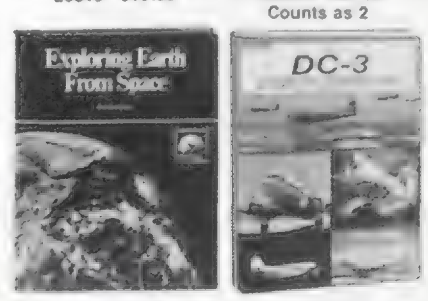

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Underwater Seaplanes

Its name means "blizzard attacking the summit of a mountain when seen against an indigo clear blue sky"—a vague hint of the Seiran's ominous mission. Catapulted off the deck of a surfaced submarine, the Japanese seaplane was to fly east in pre-dawn darkness over the Pacific Ocean. When it reached the Panama Canal, the Seiran would drop high-explosive bombs and torpedoes.

Had the mission gone forward, it would have been a surprise attack to rival the one at Pearl Harbor several years earlier. And while the strategic waterway connecting the Atlantic and Pacific oceans reeled from the blow, the seaplane would fly back to be recovered by the waiting submarine. Then both would disappear beneath the Pacific.

Of the 28 Seirans built, only one survives. It is currently being restored at the Air and Space Museum's Paul E. Garber Facility in Suitland, Maryland. A faded red rising sun is still clearly visible between the cockpit and the empennage of the weathered, dark green fuselage. Behind the aircraft, the seaplane's floats are stacked on the floor like dilapidated canoes.

"Look at the size," says Robert C. Mikesh, the Museum's senior curator and author of *Aichi M6A1 Seiran: Japan's Submarine-Launched Panama Canal Bomber.* "This is a big bomber," he says, "and to think that it went in a tube."

Even more amazing: *three* of these floatplanes fit inside a tube-like hangar built into the sub. These "underwater aircraft carriers" weren't just any submarines. Up to 393 feet in length, the supersubs were the largest conventionally powered submarines ever built, with a range that made an air attack feasible almost 8,000 miles from Japan. Mikesh has examined Japanese literature and seen discussions of the possibility of the supersubs attacking cities on the east coast of the United States.

The design of the Seiran was dictated by the constraints of the submarines' watertight hangar. Slightly starboard of center and near deck level, the hangar measured 11½ feet in diameter. Too cramped for a radial air-cooled engine, a liquid-cooled, in-line aircraft engine was selected instead. The 12-cylinder, 1,400-horsepower engine was a copy of the German Daimler-Benz DB 601, which powered the Messerschmitt Bf.109.

An ingenious folding mechanism on the wing allowed the Seiran to fit inside its hangar. Unlike many U.S. carrier aircraft, whose wings folded along a single hinge line, the Seiran's wings were first rotated leading edge downward, then folded back against the sides of the fuselage. "It's only been since we've started restoring this airplane that we've discovered how [the wings] really work," says Mikesh.

With its wings collapsed like a butterfly's inside a cocoon, the 9,800-pound aircraft was rolled from the hangar tube to the catapult launch track on a trolley car. The Seiran could be airborne within seven minutes, thanks to a minimum of adjustable parts (marked with phosphorescent paint to help mechanics work in the dark) and the warm-up of the engine while the seaplane was still in the hangar.

But production of both the supersubs and the Seiran was repeatedly interrupted. An earthquake in 1944 (ironically on December 7) heavily damaged aircraft factories. Air raids on Nagoya the following spring led to further delays.

Training persisted with target models of the Panama Canal. By 1945, however, the threat of invasion loomed over Japan. In a desperate effort the Seirans were reassigned to a kamikaze mission against U.S. Navy aircraft carriers. Two supersubs actually set sail for Ulithi Atoll, only to receive word that Hirohito, the emperor of Japan, had surrendered.

Hundreds of Seirans were scheduled to be built, but of the several dozen that were completed, most went over the side when Americans captured the supersubs. A handful were sent stateside for study but were later destroyed. The Museum's Seiran was displayed at the Naval Air Station in Alameda, California, until it was sent to the Museum. Now it sits across an aisle from the *Enola Gay,* the airplane that prompted Japan to surrender. It's a juxtaposition that forces visitors to compare what did happen with what might have.

World War II ended before the Seiran could attack the Panama Canal.

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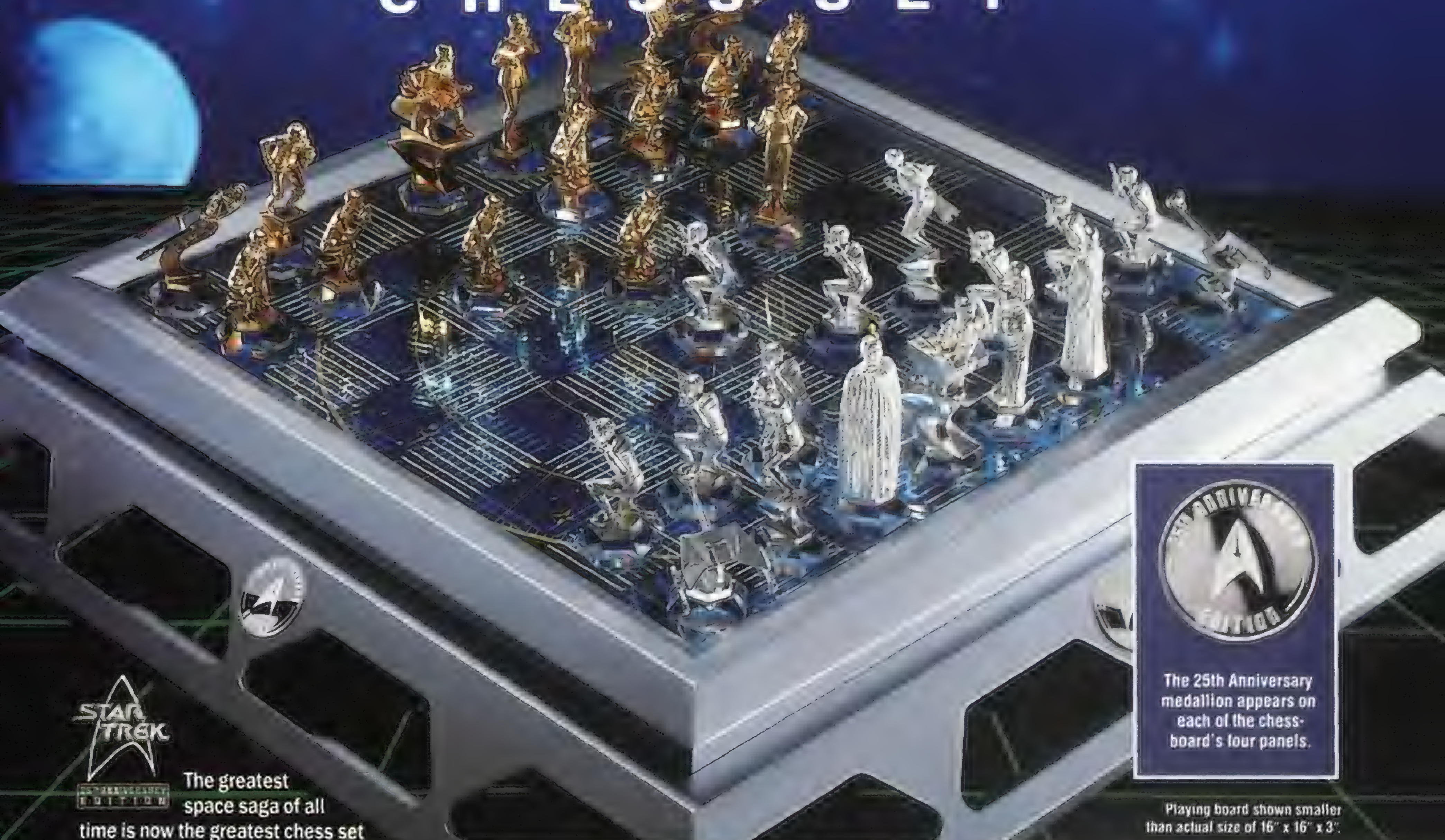

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Artifacts

NASM

In the 1930s airmail service for many rural communities in Pennsylvania and West Virginia consisted of a Stinson SR-10F Reliant and a mail bag suspended between two poles. The method, conceived by a dentist named Lytle S. Adams, was known as the Adams airmail pickup. A mail bag like the one pictured above is on display at the Museum's Paul E. Garber Facility in Maryland.

Amelia

Perhaps the last time her Lockheed Vega was surrounded by this many people was in 1932, when fans greeted Amelia Earhart in Los Angeles after she became the first woman to complete a solo flight across the United States. Nearly 60 years later Earhart fans once again surrounded her airplane, this time in the Museum's Pioneers of Flight gallery. The occasion was the presentation to the Museum of microfilm copies of the Amelia Earhart Collection from the Arthur and Elizabeth Schlesinger Library on the History of Women in America.

The 11 reels of microfilm include family papers, letters, photographs, and other material, such as news clippings, commemorative stamps, and sheet music. The contribution draws on the papers of Amelia Earhart and her mother, Amy Otis Earhart, which were donated by Amelia's sister, Muriel Earhart Morrissey, to the Schlesinger Library of Radcliffe College. The collection also includes the papers of Clarence Strong Williams, Earhart's navigational consultant.

An impressive turnout of women aviators gathered under the wings of the red, streamlined airplane to celebrate the occasion. The presence of Fay Gillis Wells provided a link between the microfilm collection and the living Earhart. Wells met Earhart in 1929, when a group of women pilots assembled in a Long Island hangar to discuss an organization that would later become the Ninety-Nines.

Members of the Ninety-Nines, the Whirly Girls, and other women's aviation groups were among the organizations represented. Said Doris Rich, author of *Amelia Earhart: A Biography,* "It was a joyful reunion."

—David Savold

NASM

Her papers are now on microfilm.

Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

Open House "Wings and Things," open house at the National Air and Space Museum's Paul E. Garber Preservation, Restoration and Storage Facility, Suitland, Maryland. April 27 and 28, 10 a.m.–3 p.m.

April 3 Special Lecture: To be announced. Admiral Noel Gayler, U.S. Navy (ret.). Langley Theater, 7:30 p.m.

April 6 Monthly Sky Lecture: "Celestial Shadows." James H. Sharp, NASM. Einstein Planetarium, 9:30 a.m.

April 10 Exploring Space Lecture Series: "Inflation!" Alan Guth, Massachusetts Institute of Technology. Einstein Planetarium, 7:30 p.m.

April 18 General Electric Aviation Lecture: "The Flying Tigers." Erik Shilling, former member of the Flying Tigers. Langley Theater, 7:30 p.m.

April 20 "Astronomy Day 1991." Includes "Calling All Stars" planetarium program, lectures, demonstrations, games, and a costume contest. NASM West Wing, 5 p.m.– 9 p.m.

May 4 Monthly Sky Lecture: To be announced. Einstein Planetarium, 9:30 a.m.

May 8 Exploring Space Lecture Series: "Extragalactic Sociology." Martha Haynes, Cornell University. Einstein Planetarium, 7:30 p.m.

May 23 Charles A. Lindbergh Memorial Lecture: "Civil Aviation and Deregulation." Welch Pogue, former chairman of the Civil Aeronautics Board. Langley Theater, 8 p.m.

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Learning Curve

ILLUSTRATIONS BY ROBERT OSBORN

Those of us making the transition from piston to jet engines in the 1950s found that we had a lot to learn. One of the most significant discoveries was the difference in throttle response between the piston engine and the early jet engines. The clever devices that now allow jet throttles to be slammed open or shut with impunity had not yet been invented, so rapid movement of the throttle in either direction could flood or starve an engine, both of which would lead to an engine flame-out and severe embarrassment—or worse—for the pilot. I began to understand just how much worse one cloudy day in the winter of 1953.

A very junior fighter pilot on my first operational tour with the Royal Air Force, I nevertheless found myself leading a pair of Meteor 8s out of East Anglia during an air defense exercise with 64 Squadron. Some "hostiles" had been reported inbound across the North Sea, and we had been scrambled to intercept them. We had taken off in close formation through driving rain, and at 800 feet we had entered cloud, which remained unbroken through the long climb on an easterly heading. We finally broke out at 30,000 feet and almost bumped into our intended targets, two U.S. Air Force F-86 Sabres just brushing the cloud tops. To my delight, they were just in front of us and turning. I left full power on and eased onto the inside of the turn to cut them off. Green and eager, I was gratified to see that the gap between my airplane and the leading F-86 was shrinking. My finger rested on the trigger and I got ready to take some superior gun camera film.

Suddenly I was closing too fast. The F-86 pilot had flicked out his speed brakes and tightened his turn into me. Instead of converting my speed into height and

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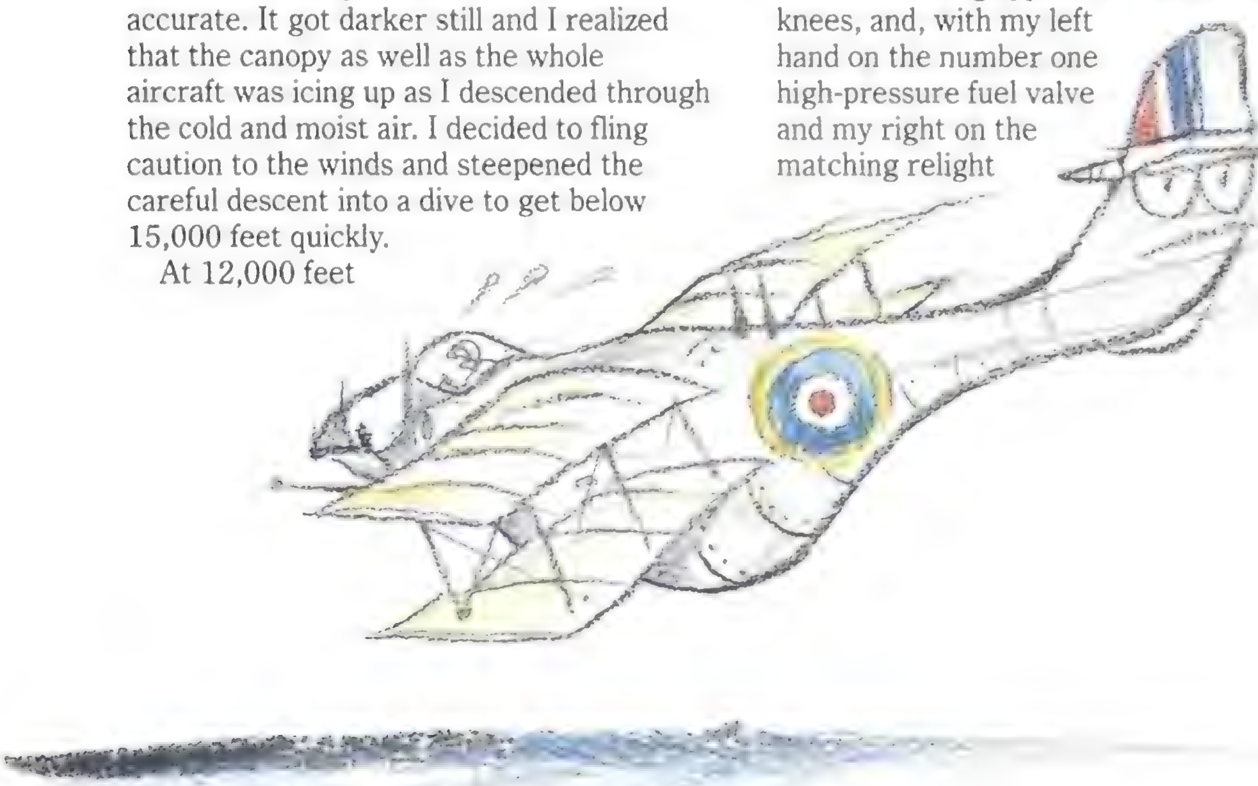
starting again, I stupidly tried to keep my gunsight on the target by committing the cardinal sin of closing both throttles and using my speed brakes too. The F-86 driver knew a novice when he saw one. As my speed brakes went out, his went in. I had been fooled: he had never taken his power off and now he began to accelerate away from me.

Annoyed, I retracted the speed brakes and slammed the throttles wide open. The engines responded with a grumbling noise and then, as they shut off and wound down, a descending pitch. My aircraft sank back into the murk from which it had so recently emerged, and both generator lights came on to confirm that I was now flying a very inefficient glider. I told my wingman he was on his own (a statement of the blindingly obvious) and turned toward the coast.

A number of problems typical of early jets now pressed for my attention. In those days engines were not enthusiastic about starting above 15,000 feet. That meant I had to glide for a while, trying not to think about the fact that I was something like 80 miles from the coast of East Anglia and facing a headwind. In addition, the capacity of the batteries was not generous, so it was important to make the first start count. Having reported my predicament to an east coast radar station, I switched off the radios to conserve the batteries and sat in silence, concentrating on flying a constant heading and an accurate best-glide airspeed.

It was very dark inside the cloud, and because the cockpit heating system relied on the engines, it rapidly became very cold as well. The temperature drop caused a thick frost to form over everything—including, to my alarm, the faces of the instruments. I scraped frantically at the glass covering the airspeed indicator. My instrument flying became less than accurate. It got darker still and I realized that the canopy as well as the whole aircraft was icing up as I descended through the cold and moist air. I decided to fling caution to the winds and steepened the careful descent into a dive to get below 15,000 feet quickly.

At 12,000 feet and still in heavy, turbulent cloud, I began the engine relight procedure. That was easier said than done. Apparently it had not occurred to the Meteor's designers that anyone wishing to relight an engine would need to do it while flying the aircraft. The high-pressure fuel valves (closed during the glide) were low down on either side of the seat, and the relight buttons (which had to be kept pressed while the engines were spooling up) were on the instrument panel. I scratched the essential instruments clear for a moment, gripped the stick with my knees, and, with my left hand on the number one high-pressure fuel valve and my right on the matching relight button, tried to maintain an airspeed that would windmill the turbines at 1,200 rpm. As the component parts of my body wrestled with the cumbersome three-way coordination problem, my eyes flickered desperately from airspeed to tachometer to turn-and-slip indicator to exhaust gas temperature and back again. The number one engine repaid these gymnastics by ignoring me.



I was now below 10,000 feet and beginning to feel a twinge of anxiety. The time when I would have to make a decision about ejecting was fast approaching. My Martin-Baker ejection seat, still new enough to be regarded with apprehension by most aviators, was a long way from the sophisticated creation of today. For one thing, it relied on a gun rather than a rocket, so its upward acceleration was violent and often damaging to the user. For another, it was a manual seat: nothing happened automatically. The pilot had to separate himself from the seat once clear of the aircraft. Those raised on the routine of sliding open the canopy and bailing out did not initially relish the thought of sitting on a high-explosive charge as they went about their daily work, nor did they like the idea of having to wrestle out of the seat before pulling the parachute ripcord. That took

time, so it was wise to make an ejection decision with plenty of height available. Of course, this was not always possible, and many pilots were forced to take their lives in their hands quite close to the ground (or water). As far as I know the lowest successful ejection on a Mark I Martin-Baker seat occurred with a ground clearance of only 350 feet. The pilot involved subsequently left the Royal Air Force and made a rewarding career in the wine trade.

But now the North Sea was waiting. I rescraped the instruments, regripped the stick with my knees, and switched hands in an attempt to light the number two engine. ***Press the relight button for five seconds, open the high-pressure valve slowly and carefully while keeping the button pressed, and watch the tachometer.*** After remaining comatose for what seemed like hours, the number two engine finally responded to my highly vocal urgings and came slowly back to life. With a generator functioning, number one duly followed. The sweat on my brow testified to the fact that I was no longer in need of the warm air that flowed into the cockpit, but the instruments welcomed it.

I tried to sound casual as I called for a standard instrument approach to base. My wingman, also homeward bound and plowing through the storm, seemed more surprised than pleased at my regeneration. He had imagined himself playing a starring role in an air-sea rescue operation. Later, he chided me for abandoning him to the mercy of the F-86s and the weather so far out over the North Sea. I assumed as much of a fatherly air as my 21 years would allow. "It's all part of the learning process, lad," I told him.

—Air Vice Marshal Ron Dick
Royal Air Force (Ret.)

Flightseeing Tour

New York City seldom draws criticism from those who enjoy art museums, fine dining, or violent crime, but it does take a beating from prop heads. Take, for example, the whinings of a typical Manhattanite weekend pilot. "To fly around Long Island for an hour I have to schedule a rental airplane two weeks in advance," he says. "Then the day of the flight I have to get up before dawn, check the weather with flight service, catch a subway, transfer to another one, connect to the commuter train, switch to one more, take a cab from the train station to Republic Airport—and then I have to cancel because in the five hours since I checked the weather a freak storm has moved in."

But a few minutes around airplanes restores his good nature. It was with such people in mind, as well as aviation-impaired visitors, that I designed a one-day tour of the island-without-an-airport.

We begin in lower Manhattan, looking south down Broadway, the route of ticker tape parades for Charles Lindbergh, the Mercury astronauts, and the Apollo 11 crew. To get an idea of what the parades were like, visit on a windy day during one of the city's garbage strikes or on a Sunday when *New York Times* readers wish to lighten the day's five-pound edition. The more affluent can rent a limousine and wave from it, pretending to have just returned from space.

Next, drop in at The Cockpit on Broadway at Prince Street, which specializes in military aviation apparel. Some grouse that the bomber jackets are overpriced and decorated with inappropriate patches ("You'd have to have flown Navy Tomcats in the Army during World War II to wear some of them," a friend sneers), but you'll also find a clipped-wing T-6 Texan trainer suspended over display cases filled with model aircraft. Pet the nose of the DC-3 on your way out.

Head north to Kiehl's 140-year-old pharmacy, on Third Avenue between 13th and 14th, where for years proprietor Aaron Morse, a World War II bomber pilot, kept a pair of Pitts Specials on display. Last year he unleashed them on the airshow circuit,

LESLIE COBER

but there are still huge color photos of the Blue Angels, the Patrouille de France, and Italy's Frecce Tricolori team lining the apothecary's walls. "You can always come and talk flying with me," he says.

Walk up Third Avenue, take a right onto 23rd Street, and keep going until you come to the East River and the New York Skyports seaplane base. On nice days you'll see Cessnas on floats ferrying wealthy commuters to and from Long Island and New Jersey. On bad days you may only spot, as I did, a pair of New York's finest dozing in an unmarked car.

Head west on 34th Street to the Empire State Building, once the world's tallest skyscraper and perhaps its most famous. Back in 1945 a Newark-bound B-25 bomber, lost in fog, slammed into the building's north face at the 79th floor. Fourteen people, including the crew, perished in the fireball, which left a hole 18 feet wide and 20 feet high. A recent NBC program titled "The Story Behind the Story" reported that you could still see unfinished masonry from the repairs. I went to the 86th floor observatory, stuck my head through the suicide fence, and could barely make out some lighter caulking around one limestone block. But an Empire State Building spokesman assured me that what NBC showed was actually part of an ongoing waterproofing project. "There's no discernible dent," he says.

Walk up to Gough's Chop House at 43rd and Broadway, where over the bar hangs a black-and-white photo taken right after the crash. Not only can Huey the bartender tell you how the *Times* photographer got the shot, he also sells the cheapest pitchers of beer in town.

From Gough's, walk west through Hell's Kitchen to the aircraft carrier-turned-museum USS *Intrepid,* anchored at 46th Street and 12th Avenue. While you wander among the 25 combat aircraft strapped to the flight deck, look up for the flotilla of small airplanes navigating the somewhat treacherous shoals of the Hudson River Corridor at less than 1,000 feet.

For dinner, head south to The Hangar on Eighth Avenue between 17th and 18th Streets. The interior, inspired by Pancho's Fly Inn in *The Right Stuff,* according to part owner Errol Hamilton, features metal from a Quonset hut, a camouflaged parachute, World War II posters, model airplanes suspended from the ceiling, and a Piper Cub wing stripped of its fabric. And you can once again hear a tape of New York air traffic control communications piped into the restroom; they've fixed the wires someone cut a while back ("It can get a little wild in here at times," says Hamilton). The food is good; I recommend the Heapin' Hangar of Nachos, but you may be content with the Plane Burger. The prices are reasonable for Manhattan.

This isn't a comprehensive tour, and I wouldn't recommend coming to New York solely to take it. But you'll see a lot of the island's lower half, and if you don't splurge on taxis, you can do it for less than the price of two tickets to *Les Miserables*—or an actual flight.

—Phil Scott


X-31
EFM

Stall Tactics

The X-31 is teaching old dogfighters new tricks.

by Preston Lerner

ROCKWELL INTERNATIONAL

On October 11, 1990, Rockwell International chief test pilot Ken Dyson became the first to fly the X-31.

If the X-31 proves as agile as its designers hope, it will turn in half the airspace required by an F/A-18.

Test pilot Ken Dyson gazes wistfully at the lithe blue and white airplane huddled in a tent near the flight line in Palmdale, California. "It's all gassed up and ready to go," he says as he zips up his flight jacket to protect himself from the frigid gusts sweeping off the Mojave. A cold front had blasted through southern California the previous night, blowing the smog out of the Los Angeles basin and leaving strong winds in the high desert. The blustery weather had forced NASA to divert the returning space shuttle from nearby Edwards Air Force Base to Cape Canaveral, Florida. It also left Rockwell International, Dyson's employer, no choice but to scratch the eighth test flight of the X-31.

"It's a pretty little bird, isn't it?" says Dyson. Surprisingly it is, not at all what you'd expect of the aircraft that's supposed to rewrite the rules of close-in fighter combat. Maybe it's the sporty paint job or the compact dimensions, but the X-31 has none of the ferocity of an F-15. And compared with the futuristic X-29, the Grumman research aircraft currently making test flights over the Mojave on strange, forward-swept wings, the X-31 is modest and unassuming. But don't be deceived by its conventional appearance. Although the airplane may look like Clark Kent, its creators say it will perform more like Superman.

Developed jointly by Rockwell and Messerschmitt-Bölkow-Blohm (MBB) with funding from both the U.S. and German governments, the X-31 is the first international X-plane. And like its ancestor, the Bell X-1, which shattered the sound barrier on October 14, 1947, the X-31 is designed to fly in an uncharted region of aerodynamics: in its case, the post-stall regime.

From the dawn of flight, pilots have tried to avoid stall—the point at which wings cease functioning like airfoils and assume the low-lift, high-drag characteristics of, say, two-by-fours. But Ken Dyson's job will be to stall the X-31 and continue to fly it. He will be able to do so by virtue of the X-31's unique combination of control surfaces and a technique called thrust vectoring. "People call it magic. It's not magic. It's all physics," says Lieutenant Colonel Tack Nix Jr., the X-31 program manager for the Defense Advanced Research Projects Agency (DARPA), which provides roughly 70 percent of the funding for the project.

The only visual clue to the X-31's experimental pedigree is a trio of paddles protruding from the rear of the fuselage. By maneuvering these spoon-like vanes into the exhaust plume, the X-31 can deflect its thrust 10 degrees from the center line. Thanks to this thrust vectoring system, which is integrated with the automated flight control system, pilots theoretically will be able to hurl the airplane into a steep 70-degree angle of attack and—here comes the weird part—point the nose away from the flight path. In other words, the airplane will be moving one way and the nose will be pointed another, a move somewhat comparable to a race car skidding through a turn on a dirt track. The name for this trick is flight path decoupling, and it will enable the X-31 to turn in about half the airspace required by conventional aircraft. Not for nothing is the X-31 known officially as the Enhanced Fighter Maneuverability demonstrator.

What does all this mean for fighter pilots flying against enemy aircraft? Extensive simulator tests suggest that the superior agility of fighters based on the X-31 model will double or triple their chances of scoring a kill against conventional foes. But nobody will be sure until the end of the flight test program. The first 98 flights of the X-31 will test only its airworthiness and conventional handling characteristics. It will take an-

MARK MCANDLESS/ROCKWELL INTERNATIONAL

CAROL PETRACHENKO/NASA LANGLEY

Lighted wingtips of a model X-31 trace patterns in a spin—a maneuver the full-scale aircraft can avoid.

other 200 flights to prove its post-stall capabilities. Only then, in early 1992, will Rockwell and MBB turn the aircraft over to the military to test its combat effectiveness, which pilots will do by flying 120 demonstration sorties.

Even if the X-31 surpasses all expectations in the first two parts of the test program, it could still flunk the tactical exam. It wouldn't be the first time that a machine performing exactly as designed put its pilot in harm's way.

The McDonnell Douglas F-4 Phantom II pilots freshly assigned to Ubon Royal Thai Air Force Base in 1966 knew they couldn't turn with the MiG-17s they would encounter over Vietnam, but they weren't worried. After all, they had a technological advantage: radar-guided Sparrow missiles, which they could shoot well before they flew within range of the MiG-17's cannon. And if the Sparrows didn't do the trick, then the short-range, heat-seeking Sidewinders would.

But when the Americans finally met the MiGs, their Sparrows went awry. Either the aircraft's radar failed and the pilot couldn't shoot the missiles, or the radar found the target but the missile's guidance system failed. In any case, the pilots' long-range defense had disappeared and they found themselves in lethal close-in combat, known to pilots as a "knife fight" or "fighting in a phone booth." The Americans then discovered that their Phantoms were so clumsy in comparison to the MiGs that they couldn't get into position to fire their Sidewinders. Because those missiles tracked on exhaust plumes, the pilot had to maneuver into a classical position behind his adversary before he could get a shot off. A cannon would have come in handy, but U.S. Air Force planners, convinced that dogfights were a relic of a bygone age, had decided not to equip the first-generation Phantoms with guns.

Although the development of long-range missiles during the 1960s seemed to presage the death of close-in combat, Vietnam War scenarios like this proved

The Heart and Soul of the X-31

Just aft of the cockpit are four components that are as necessary to fly the X-31 as the pilot who will sit in front of them: the flight control computers. In the rear of the fuselage, a GE-400 engine provides up to 16,000 pounds of thrust.

ROCKWELL INTERNATIONAL

that prediction had been too optimistic. In the beginning of the air war over Southeast Asia, the avionics required to find an enemy aircraft, confirm it to be a foe, and shoot it out of the sky was simply immature. Recognizing this weakness, the Pentagon imposed rules of engagement that required pilots to identify targets visually before firing their missiles. Certainly radar systems have improved since that time, but so have the stealth techniques invented to evade or jam radar. Based on countless simulations designed to study *beyond*-visual-range encounters, DARPA manager Tack Nix believes the knife fight is inevitable in air combat. "A significant percentage of the simulations—the exact number is classified—deteriorated to within visual range, even when the test was designed to avoid it," he says.

The American experience in Southeast Asia demonstrated a further basic truth: Agility was as key to surviving a knife fight over Vietnam in 1968 as it had been in a dogfight over France in 1918. "You're constantly trying to drive your adversary to a corner of the envelope where he's inferior," says Nix.

A new breed of weapons—"all-aspect" missiles, which can track on the heat produced by the leading edge of the wing, nose, or canopy pushing against the air—were introduced after the war. As long as he could lock his missile onto the target, the pilot no longer had to maneuver behind an enemy craft. But the so-called point-and-shoot missiles didn't eliminate the need for maneuverability; they increased it. Although the pilots could now destroy just about anything they could see, their airplanes weren't agile enough to keep them from being killed at the same time by an enemy with similar technology. In fact, simulations between more or less evenly matched adversaries repeatedly showed that the most common outcome of close-in battles was a mutual kill.

Into this impasse strode MBB engineer Wolfgang Herbst, the spiritual father of the X-31. Herbst, director of advanced design in MBB's military aircraft division, reasoned that incremental reductions in the turning radii of conventional aircraft would not produce a significant advantage in the all-aspect missile environment. What was needed, he decided, was an exponential advance in agility. Working backward, he realized that the slower an airplane flies the more agile it becomes, and what quicker way to slow down a supersonic fighter than to provoke a stall? "By maneuvering beyond stall limits, you can make very tight turns," he explains. "This gives you a time advantage. It enables you to fire a little bit quicker than your opponent."

The situation usually cited to showcase the beauty of post-stall maneuverability involves two fighters making a head-on pass. Immediately after they pass each other, the conventional fighter banks sharply and executes a high-G turn. Meanwhile, the pilot of the super-maneuverable aircraft yanks the nose up, stalls the wings, yaws the tail around and fires while his adversary is still turning (see "Faster on the Draw," p. 34). Simulator tests have identified his time advantage as five to seven seconds. In combat, that could easily be the difference between life and death.

The essence of post-stall maneuvering is making an asset out of a liability. In a stall an airplane's control surfaces can't grab and work the air. "It's like disconnecting the steering wheel on your car at 65 miles per hour," Rockwell executive Sam Iacobellis told reporters at the X-31 rollout on March 1, 1990. "But in the X-31 you can get out of it. It is a natural progression in moving past [the stall] barrier."

A wing stalls when air cannot flow smoothly past its leading edge. When the wing is angled up sharply, for example, air flowing past its surface becomes turbulent, and the wing no longer produces lift. Most conventional aircraft stall when the angle between the wing and the airstream—called the angle of attack, or "alpha"—reaches about 20 degrees (see "Dynamic Stall," a do-it-yourself animation on the opposite page). It is important to understand that the angle of attack is the position of the aircraft relative to the air flowing past it, not to the horizon. A powerful fighter in a vertical climb is flying at a very low angle of attack, even though it is oriented 90 degrees from the horizon.

Research on high-alpha flight is decades old, but airplanes that can put it to use, thanks to more effective control surfaces and high-lift aids such as canards, are just now being built. In the past, certain aircraft could remain stable at high angles of attack, but they couldn't do much in the post-stall regime. Pilots who tried to maneuver at or beyond the stall limit risked provoking a potentially fatal spin. That's why a fighter as agile as the F-16 is equipped with an angle of attack limiter that counters a pilot's attempts to pull an alpha higher than 25 degrees.

The X-31, on the other hand, will test dynamic maneuvers—notably sharp turns—at angles of attack up to 70 degrees. In other words, post-stall stability isn't the goal; it is merely the means to the considerably more dramatic end of post-stall maneuverability. One of the reasons that the X-31 can maneuver in the post-stall regime is that it doesn't have to depend on a rudder.

Rudders are notoriously ineffective at high angles of attack. In level flight the pilot produces yaw, the rotation of the aircraft around its vertical axis, by deflecting the rudder into the airstream. As the angle of attack increases, so does the rudder's angle to the airstream, and its strength decreases. At a very high angle of attack, the rudder is almost parallel with the airflow and has no effect on it. In fact, at angles of attack beyond 45 degrees, the rudder on the X-31 is completely disabled. The dilemma facing the X-31 designers, therefore, was how to generate yaw without an effective rudder—that is, at high alpha.

Herbst's solution was to harness the propulsive power of the engine to help control the aircraft. He reasoned that thrust could be angled, or vectored, to perform in a limited fashion the role that small reaction control thrusters play when adjusting the attitude of a spacecraft. So the thrust vectoring system on the X-31, besides providing the pilot with extra pitch authority, is the sole source of yaw in the post-stall regime.

The potential advantages of high-alpha flight are so great that three U.S. research vehicles in addition to the X-31 are exploring the territory: the X-29; the STOL Technology Demonstrator, an F-15 that's been retrofitted with a thrust vectoring nozzle and is testing short-takeoff-and-landing technology for the Air Force; and an instrument-packed NASA F/A-18 called HARV, for High Alpha Research Vehicle, equipped like the X-31 with multi-axis thrust vectoring paddles.

Showing off in a Soviet Su-27 at the 1989 Paris airshow, Sukhoi test pilot Victor Pougachev performed a stunt that has become known as Pougachev's Cobra. The huge fighter

AVWEEK (3)

DALE GLASGOW

On Your Mark, Get Set, Super-maneuver

Speed brakes (aft of the wings) and thrust vectoring paddles, shown in their starting positions, can help slow the X-31 rapidly when deflected outward. Thrust is then vectored upward to help leading edge flaps pitch the aircraft to about 35 degrees. At 70 degrees, wings are stalled and ready for super-maneuver.

begins the sequence (1) at about 250 mph. The pilot pulls the nose up (2), and the aircraft decelerates but does not climb appreciably. The pilot pitches the aircraft to about 120 degrees and slows to about 75 mph (3) before dropping the nose and accelerating. The pilot does not attempt to maneuver during the radical pitch-up.

1

READ the back of this card to find out what's going on in the pictures.

2

DYNAMIC STALL

3

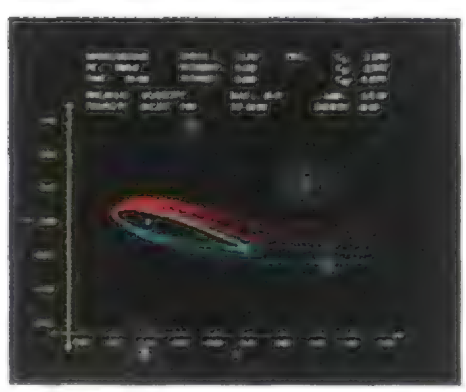
If you cut out, assemble, and flip these panels, you will see the action of the air that causes an airplane wing to lose its lift.

4

Instructions:

CUT along the dotted lines.

STACK the panels in order with #1 on the top and #12 on the bottom.



5

LINE UP panels #1 through #11 so that their right edges correspond to the numbered gauge on panel #12. Then replace panel #12 on the bottom with its right edge protruding slightly. This will make it easier to flip the panels and create the animation.

6

STAPLE in the spot indicated on panel #1.

FLIP the panels as though you were flipping the pages of a book.

7

cut here

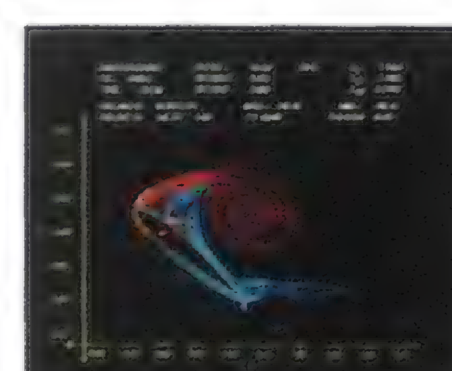
cut here

8

9

10

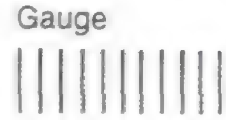
11

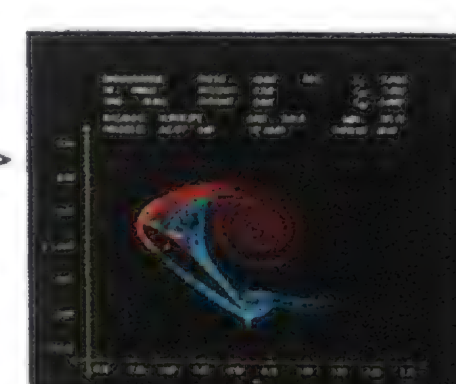


12

stack panels

Gauge





DYNAMIC STALL

Aerodynamicists know that an airplane wing stalls—suddenly loses its lift—when the air flowing over it separates violently from the upper surface. What they want to understand better is the exact motion of the air that causes the stall and the exact instant when the benefit of increasing lift by angling, or pitching, a wing upward changes to a penalty by causing the wing to stall. These pictures show what happens to the air flowing around an airfoil that pitches up rapidly. They were created by researchers at the University of Cincinnati using a computer at the Ohio Supercomputer Center to predict the path and motion of each fluid particle in the air surrounding the airfoil. These predictions were assembled to create a video animation that provides further insight into the flow phenomenon of dynamic stall, a stall that results from a rapid maneuver.

In panel 1, the airfoil is in level flight, and the airflow past it is smooth and attached. As they stream past the airfoil, the individual fluid particles spin as a result of the viscosity that any fluid, including air, possesses. The red color above the airfoil indicates that the particles are spinning clockwise; the blue beneath the airfoil indicates particles spinning counterclockwise. The colors help show the boundary layers on the airfoil surface as well as the viscous wake behind the airfoil.

In panels 2 through 5, the airfoil increases its pitch, and the airflow begins to separate at the trailing edge of the wing. Note that the blue color appears along the airfoil's upper surface, displacing the previous red-colored boundary layer. This displacement begins the series of events that will lead to dynamic stall, but so far, all is well; lift is increasing dramatically.

In panel 6, as the pitch increases, the clockwise-spinning particles have begun to interact with those spinning counterclockwise at the trailing edge. In panel 7, when the small blue bubble appears on the upper surface near the leading edge, the strength of the force perpendicular to the airfoil's lift, called drag, increases. The numbers in the upper right-hand corner of the square record the strength of these forces.

By panel 8, the interaction of counter-spinning streams has formed a vortex, which intensifies rapidly. The numbers in the corner show significant changes in the forces acting on the airfoil. As the large red vortex grows in panels 9 through 12 and is driven away from the airfoil's upper surface by an eruption of the blue counter-rotating material directly beneath it, dynamic stall occurs. In actual flight an aircraft would buffet and could tumble.

By studying the dynamics of the evolving vortices, scientists hope to discover some technique, a sucking or blowing mechanism, possibly, to delay the onset of dynamic stall until higher pitch angles are reached.

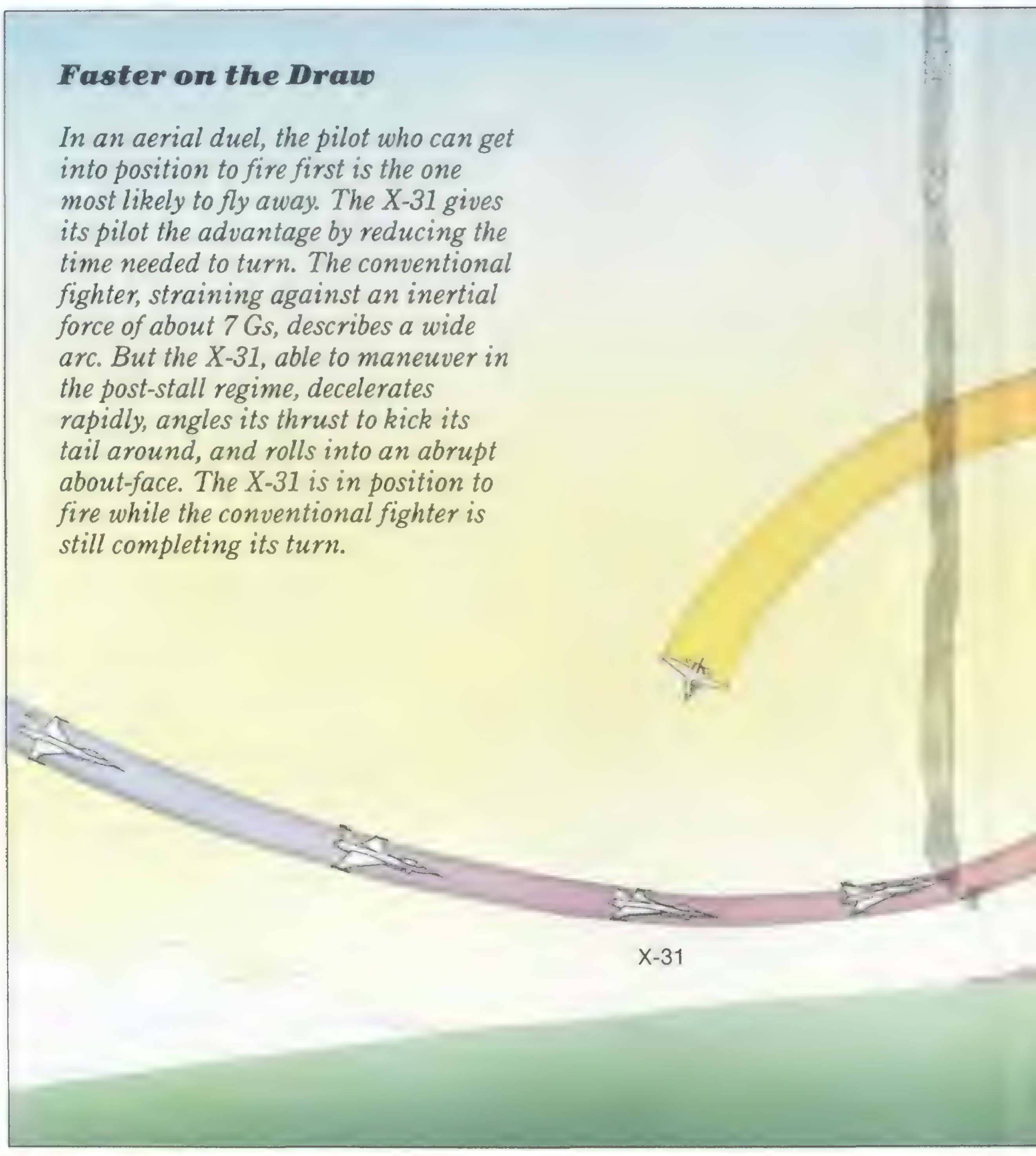
Illustrations and text courtesy of K.N. and Urmila Ghia and Gary Osswald

NASA

ROCKWELL INTERNATIONAL

Smoke relased from tiny ports at the nose of NASA's F/A-18 shows airflow patterns at high alpha (top).

Among the components the X-31 borrowed from other aircraft is the cockpit from an F/A-18.



Faster on the Draw

In an aerial duel, the pilot who can get into position to fire first is the one most likely to fly away. The X-31 gives its pilot the advantage by reducing the time needed to turn. The conventional fighter, straining against an inertial force of about 7 Gs, describes a wide arc. But the X-31, able to maneuver in the post-stall regime, decelerates rapidly, angles its thrust to kick its tail around, and rolls into an abrupt about-face. The X-31 is in position to fire while the conventional fighter is still completing its turn.

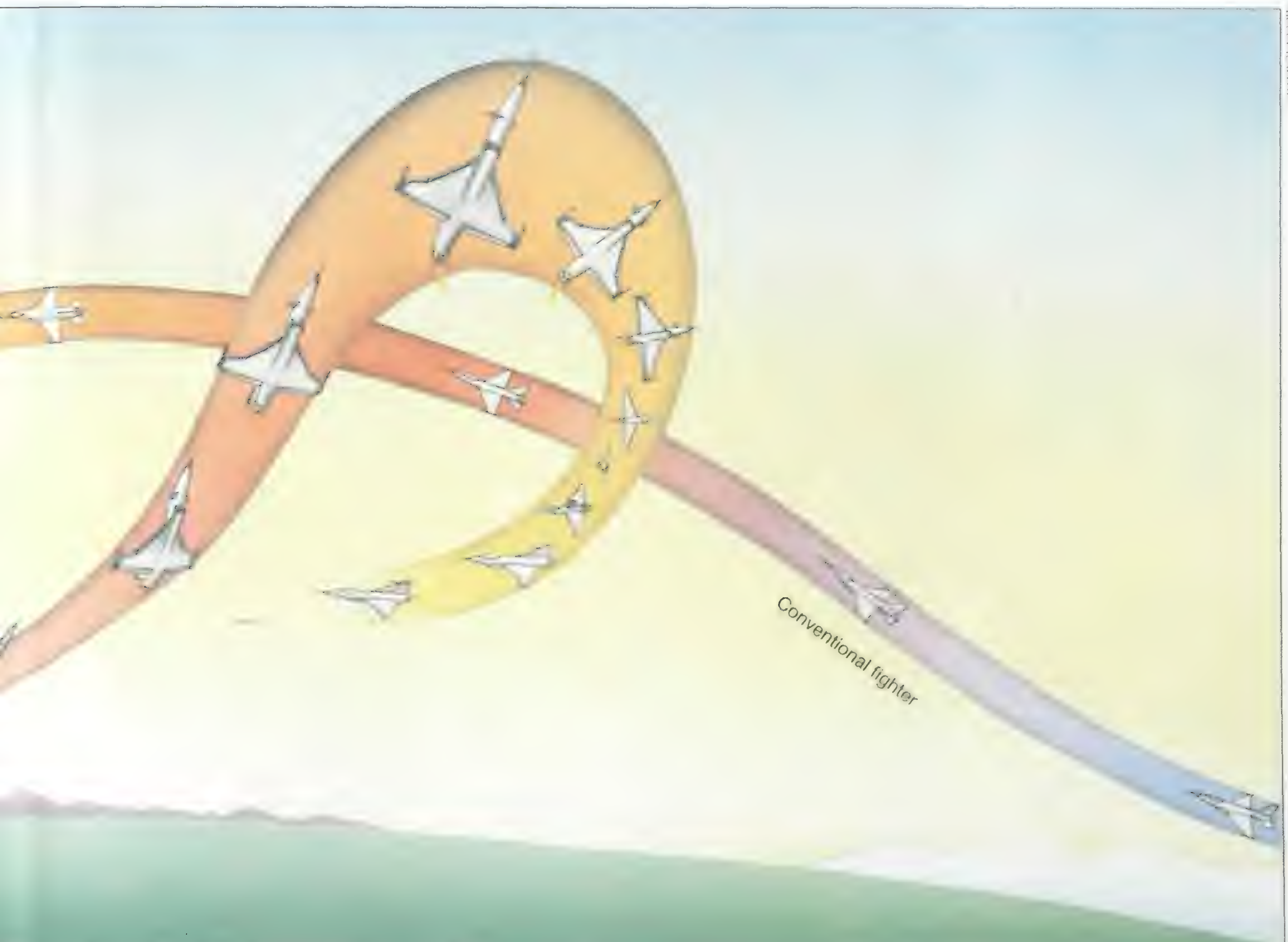
Whatever these four research programs eventually determine about the superior agility of high-alpha aircraft, they start with the realization that agility comes at a price: loss of speed. The X-31's tactical tests will determine whether, for a fighter pilot, that price is too high.

In 1977, MBB ran its first computer simulations of a generic super-maneuverable aircraft equipped with a thrust vectoring system capable of controlling both pitch and yaw. The results were astounding. So was the lack of response from the aviation community. Industry requests for funding to develop post-stall technology were rejected by the German military and by the sponsors of the British Agile Combat Aircraft (now the Experimental Aircraft Program) and the European Fighter Aircraft. "The idea of maneuvering beyond stall limits is something that takes a while to understand, and many people weren't willing to take the time," Herbst diplomatically explains. Furthermore, post-stall maneuvering contravenes the oldest tenet of the fighter pilot's bible: Speed is life. This doctrine is so firmly ingrained in the collective consciousness of the tactical fighter community that the usefulness of post-stall flight in combat is still widely questioned.

Even the champions of the X-31 concede that post-stall maneuverability is only one weapon in a fighter pilot's armory. In many scenarios—a dogfight involving more than a handful of aircraft, for example—going post-stall, with the attendant loss of speed, could make the pilot a sitting duck. But in the right situations, the ability to pivot and shoot could be very convenient.

"There's always been a mindset that says you don't want to go beyond the stall barrier," says Leslie M. Lackman, Rockwell's vice president for research, engineering, and advanced systems. "This program is going to be a real barrier breaker."

The barrier was softened up a little at the 1989 Paris Air Show, where Sukhoi chief test pilot Viktor Pougachev, flying a Soviet Su-27, stunned the audience with a maneuver that has come to be called Pougachev's Cobra. Pougachev snapped the fighter into a radical beyond-vertical attitude and seemed to skid forward for a few seconds before lowering the nose and accelerating. Although he didn't turn the craft, the sight of a Soviet fighter leaning backward



probably convinced some at the show that the time was right for investigating the post-stall regime. Tack Nix was in the crowd that day. He remembers saying to his colleagues, "We better get on with the program a little faster."

The real impetus for the X-31 program, however, was an aviation conference seven years earlier at which Herbst chanced to meet Mike Robinson, then Rockwell's project manager for advanced prototypes. At the time, both companies had just been dealt major disappointments: MBB had failed to interest anybody in Europe in super-maneuverability, and Rockwell's bid for the X-29 contract had been rejected. Once Herbst and Robinson discovered all they had in common, they approached DARPA and the German ministry of defense for funding. At DARPA, they met Lieutenant Colonel James Allburn.

Allburn, now retired, remembers that "Wolfgang and Mike didn't have to do much selling. I was primed. I was a former Air Force fighter pilot who had

The X-Plane With a German Accent

The X-31 bears a distinct resemblance to the German-inspired European Fighter Aircraft, a compact, single-seat design with clipped, double-delta wings and a canard just aft of the cockpit.

ROCKWELL INTERNATIONAL

Ken Dyson tests the deployment of the X-31's spin recovery chute, the pilot's ace-in-the-hole at high alpha.

flown F-4s and F-100s, both of which are not very forgiving at high angles of attack and both of which are very departure-prone, and I realized that we needed to expand the maneuvering envelope." Allburn had also spent many years as an instructor pilot and had "been in so many spins" that he was predisposed to favor an aircraft that was handy at avoiding them.

Rockwell and MBB concluded a feasibility study in 1986 and divvied up the development responsibilities. MBB took the flight control system and design and fabrication of the wings and thrust vectoring paddles—and Rockwell took the balance. Two airplanes have been assembled from newly fabricated structures and off-the-shelf subsystems, the latter of which constitute nearly half of the airplanes' components. Each X-31 is a little bit F-16, a little bit V-22, a little A-7D, even a little Cessna Citation III (the wheels and brakes). Both aircraft are being tested in Palmdale and Downey, California, where MBB and the German military now have a team of two test pilots and a dozen engineers working with Rockwell.

ROCKWELL INTERNATIONAL

MBB manager Wolfgang Herbst developed the concept of using thrust as a means to help control the X-31.

Sometimes even the wildest ideas start to make sense as the years pass. A decade ago most people weren't willing to take the time to grasp what post-stall maneuverability was. Now they can't wait to see how it works.

"The whole question is whether a pilot can really use these capabilities," says Mark Croom, an aerospace engineer at NASA's Langley Research Center in Virginia, which has been involved in the X-31 program virtually since its inception and is still testing models of the airplane. "What are the pilot's sensations?" asks Croom. "What will he feel like when he's rolling 90 degrees and can't even see where he's pointed? You can do all these mathematical simulations that show all sorts of benefits, but what good are they if the pilot can't use them?"

Test pilots have performed countless maneuvers in Rockwell's 24-foot, high-dome X-31 simulator in Downey without any significant difficulties. Of course, the one great shortcoming of simulator training is that it fails to replicate the sensation of flight, and it's precisely the sensation of post-stall maneuvering that remains the great unknown of the X-31.

"A lot of the maneuvers look like yaw," says Captain Bob Trombadore, a Marine Corps fighter pilot who will lead the tactical utility tests of the X-31 and who has already put in hundreds of hours on various post-stall flight simulators. "This means a lot of side force, which is kind of uncomfortable and which most people associate with a plane that's about to go out of control."

Post-stall maneuvers will obviously require pilots to resist responses learned during a lifetime of flying. Making sense of a situation in which the nose is pointed one way and the plane is traveling another is going to take practice and maybe some help from instruments. Dietrich Seeck, MBB's chief test pilot and the second man to fly the X-31, says it may ultimately be necessary to fit super-maneuverable aircraft with head-up displays that give pilots visual cues about how the airplane is positioned with respect to both the horizon and its flight path.

Potential obstacles aside, it takes only a few minutes in Rockwell's simulator to become a believer in super-maneuvers. First of all, the handling of the aircraft is what Rockwell calls "carefree"—"idiot-proof" is more like it—which is to say that the airplane defies virtually all attempts to force it out of control. Second, the X-31 turns almost instantly, with none of the long, graceful arcs described by conventional aircraft. It's probably the only airplane in the world that performs the way you'd expect if your sole flying experience had been acquired in a video game arcade.

With Rockwell test pilot Fred Knox at the controls of the simulator, it's also easy to appreciate the tactical promise of post-stall flight. A former Navy fighter pilot who was the third man to fly the X-31, Knox demonstrates the tight 180-degree reversal known in military parlance as a "high yo-yo." Flying at about 300 mph and 10,000 feet, he pulls back on the stick to pitch the aircraft to a 30-degree angle of attack. Once he has bled off enough airspeed, he yanks back on the stick all the way and to the right. As the angle of attack reaches 70 degrees, the airplane itself acts as a speed brake, and airspeed is slowed further by the stalled condition of the wings. The craft slows to less than 60 mph and climbs to 12,500 feet. In less time than it's probably taken to read this explanation, thrust deflectors and flaperons, controlled by a set of four computers, have yawed the airplane around to the right to face in the opposite direction. Knox pushes the thrust lever to full power and pushes the stick full forward to regain airspeed and return to his original altitude.

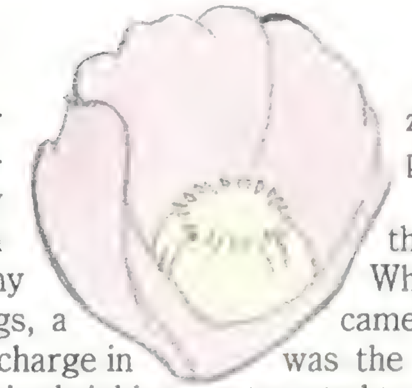
Not surprisingly, Knox is completely unconcerned about performing that maneuver in the sky. "You can't do anything to hurt this airplane," he says, adding: "It's an extension of the conventional envelope. It will extend our ability to roll the airplane about high angles of attack, but it's not going to be a whole new world. I hope that as we extend the airplane, we extend [the pilot's] envelope at the same time."

"My Body Will Collapse Like a Falling Cherry Blossom"

Near the end of World War II,
a corps of Japanese airmen
volunteered for a desperate scheme.
They called themselves the
Thunder Gods.

Illustrations by Greg Harlin, Stansbury Ronsaville Wood Inc.

by Hatsuho Naito



"That's going to be your coffin." Higher Flight Petty Officer Motoji Ichikawa followed his friend's gesture. The new weapon he and the other Thunder Gods had been told of, the *Ohka,* or "cherry blossom," was a tiny plywood-and-aluminum aircraft with stubby wings, a primitive, cramped cockpit, and a large explosive charge in its nose—no more than a manned bomb. Ichikawa's shrinking confidence diminished still more as his friend explained that the Ohka would be carried aloft under a Betty bomber and dropped in the vicinity of its target. The pilot would enter its cockpit shortly before it was dropped to guide it. "Don't be so disappointed," he was told. "If you crash-dived in an attack bomber, no one would be watching you die. In this thing, you'll be diving in front of the entire crew of the mother plane."

Like Ichikawa, the Thunder Gods were new to their duties and still struggling to come to terms with them. The Thunder Gods Special Attack Corps had been officially formed the previous month—October 1944—as an act of desperation. The tide of the Pacific war had turned against Japan, and U.S. forces were steadily advancing toward the Japanese home islands. In a last-ditch effort to ward off invasion, Japan had added suicide to the national arsenal.

That September, Japanese military leaders had organized the so-called T-Attack Corps to begin carrying out suicide attacks in Zeros. The "T" was a reference to the typhoon that had halted a 13th century Mongol invasion, known to the grateful Japanese as a "divine wind," or *kamikaze.* But as the war situation worsened, even the T-Attack Corps was not enough. The leaders began to pin more and more of their hopes on the volunteer Thunder Gods pilots and their Ohkas.

But at Konoike Air Base, the Thunder Gods' training facility east of Tokyo, the atmosphere was anything but hopeful. The Thunder Gods' first attack was to be launched from Japanese-held Clark Field on the large Philippine island of Luzon, but a series of setbacks had delayed final preparations for the attack again and again. The strain of facing certain death was taking its toll on the Ohka pilots.

Relations between the petty officers and the reserve officers, many of whom had only 90 days of training and were barely able to maintain horizontal flight, aggravated the strain. Reacting to their extraordinary position, the petty officers chosen as Ohka pilots had begun to manifest marked anti-organizational behavior. When some reserve officers responded by tightening discipline, the petty officers became further incensed. One repeatedly went to Senior Reserve Officer Hachiro Hosokawa and warned him that there was a serious morale problem in the Ohka squadron. Too inexperienced to perceive the real problem behind the petty officer's complaints, Hosokawa did nothing.

On January 8, 1945, a troupe of entertainers visited the base. The show seemed to relax the men somewhat, but as the pilots started returning to their barracks, one of the petty officers walked on a lawn that was off limits, and an especially zealous reserve officer struck him. Enraged, the petty officers began talking about getting revenge.

The yard between the reserve officers' billets and the petty officers' barracks was lit by a bright moon. When some of the newly arrived reserve officers came out into the yard and began admiring the moon, it was the last straw for the petty officers. When one attempted to seize the offending reserve officer and was himself seized, the base broke out in chaos.

The two groups spilled out into the yard and began grappling, punching, and mauling each other. The officer of the day and several others tried to stop the fighting, but the riot continued for nearly an hour.

Suddenly someone standing on a podium in the center of the yard cried out: "Petty officers withdraw!" The voice belonged to Special Service Sub-Lieutenant Shoichi Ota, the mastermind of the Ohka plan, a man who had worked his way up from fourth-class seaman and was greatly respected by all of the petty officers. Their frustrations and energies spent, the petty officers obeyed Ota and returned slowly to their barracks, many nursing bruises and other wounds.

When the petty officers remained defiant the next day, however, a legal officer was dispatched to the base to set up court martial proceedings. Training was suspended and a curfew imposed.

Despite the curfew, several of the veteran petty officers regularly sneaked into town to drink and carouse. They reasoned that since they were to die soon, the rules did not apply to them. Though also facing death, the reserve officers tended to take their duties more seriously and stayed on base.

However, one of them, Sub-Lieutenant Mitsutaka Nishio, had fallen in love with an inn maid named Taeko in the nearby town of Sawara. Nishio's friends were aware that he had been smitten by the girl and felt sorry for him. Though wartime complications prevented them from marrying, Nishio, knowing he was soon going to die, wanted to somehow formally declare his love for Taeko.

Under cover of darkness, Nishio and his two best friends, Nakane and Yasui, left the base by the rear gate and rode their bicycles into Sawara. Arriving at the inn, they took a room, ordered sake, and asked for Taeko.

As soon as she appeared and sat down on a cushion next to Nishio, Taeko knew from the men's grave and subdued manner that their time was approaching. When Nishio declared his intentions, she burst into tears.

In strained silence, Nishio's friends took turns filling the small sake cups. He and Taeko exchanged several drinks in a solemn, improvised ritual. In the meantime, other maids in the inn prepared a bridal bed for them.

There were no words the young couple could say to ease their agony. Finally Nishio got up. As if in a trance, Taeko also stood. "I want both of you to come with us," Nishio said to his friends.

Nakane and Yasui were shocked. The tone of Nishio's voice and the look on his face told his friends that he was serious, but they could not bring themselves to comply with his request. Finally realizing they were too embarrassed, Nishio led Taeko out of the room and down a hallway to the bridal room.

Two mattresses were laid out side by side. Nishio crawled into one of them, and Taeko got into the other. They joined hands and held onto each other tightly for several minutes, their eyes closed.

Finally, Nishio opened his eyes. "All right," he said, standing up, "I can go now without feeling any anxiety." Taeko stayed in the room. Beneath the quilt, she sobbed quietly.

The leader of the Thunder Gods' Betty squadron, Lieutenant Commander Goro Nonaka, had made some final preparations as well, having already sent his personal belongings, including his favorite tea ceremony kit, home to his wife.

Always outspoken, Nonaka had been vocal in objecting to the Ohka plan. He had long been haunted by the memory of his brother, Shiro, who had been forced to kill himself following an ill-fated uprising against the government in 1936. Nonaka always carried Shiro's picture. "According to the plan," he complained to a fellow Betty squadron leader, "after the Bettys drop the Ohkas they will return to base to prepare for another flight. Do you think we can do such a thing? Our men, the ones we have been living with, are being escorted to their deaths in the bloodiest and most cold-hearted way possible. Do you think we can leave them and return again and again? On my first mission I'm going to crash-dive myself. There is no other way."

As a Betty squadron leader, Nonaka had a house in the nearby town. In mid-January, as the time for their first mission grew closer, the Thunder Gods were allowed visits from their families. At the urging of Commander Motoharu Okamura, Nonaka went home late one evening to see his wife and children. It was exceptionally cold, and the ground was covered with a thin layer of snow. The following morning, standing outside the doorway preparing to leave, Nonaka was suddenly struck by the urge to dance with his wife. He held her as he hummed Strauss' beautiful *Frühlingsstimmen.* As they danced they left a double circle of footprints in the snow.

On January 20, 1945, in response to Japan's worsening position, the commander-in-chief of the Combined Fleet, Admiral Soemu Toyoda, ordered the 11th Aviation Group, which now included the Thunder Gods Corps and the T-Attack Corps, to move to the Japanese island of Kyushu. The main force of the corps set up command headquarters at Kanoya Air Base in Kyushu. Members of the Betty squadron and the covering fighter squadron were dispersed among several other bases in the area.

When the Thunder Gods had been assigned their quarters they re-hoisted banners Nonaka had flown at Konoike reading "HI-RI-HO-KEN-TEN" and "NAMU-HACHIMAN-DAI-BOSATSU." Both were favorite sayings of the famous mid-14th century general Kusunoki Masashige, who had attempted to help the Emperor regain power from the ruling shogun and killed himself when he failed. HI-RI-HO-KEN-TEN was an acronym for "Irrationality can never match reason—

Reason can never match law—Law can never match power—Power can never match Heaven." The inscription on the second banner was a popular Buddhist prayer.

By late February, it had become obvious that the United States was planning a full-scale attack on the Japanese mainland. Massive air raids on Toyko and surrounding industrial areas had begun, U.S. airplanes were making daily reconnaissance flights over Kyushu and the main island of Honshu, and movements of U.S. submarines had become more intense and were extending closer to Japan.

On March 17, the commander-in-chief of the Fifth Naval Air Fleet, Vice Admiral Matome Ugaki, issued orders for the implementation of "First Tactics," which called for a radar scout patrol that night, a torpedo attack on U.S. ships at dawn, and an attack by the Thunder Gods during the day.

The next day, the order for the Thunder Gods' first mission came at 12:13 p.m. Okamura ordered 18 Bettys from the squadron at Usa Naval Air Base, on northern Kyushu, to get ready. Working at a frantic pace, personnel at Usa pulled the Bettys out of their shelters and began bringing the Ohkas from their secret tunnels. Corps members not scheduled to participate in the mission helped the ground crews ferry the bombs

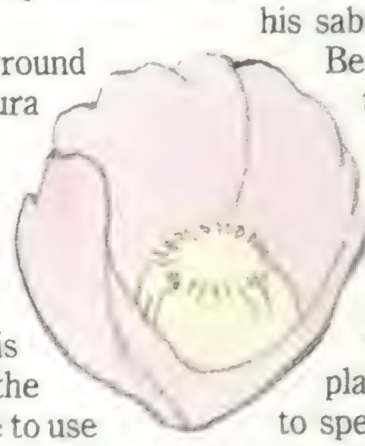
across the runway to the waiting Bettys.

Suddenly, a group of U.S. dive-bombers burst through the clouds hanging over the field and began raining down bombs. The ground crews and their Thunder Gods helpers scattered. One after the other, the Bettys on the runway and several still in shelters went up in flames. One of the air raid shelters suffered a direct hit that killed several Thunder Gods. Miraculously, none of the Ohkas was hit.

Meanwhile, U.S. bombers also attacked Tomitaka Air Base, which housed the fighters intended to protect the Ohkas. When the bombing finally ended, approximately half of the fighters had been destroyed.

The Fifth Naval Air Fleet was trying to bring some order out of the chaos, but communications between the bases had been destroyed, so fleet headquarters could not fully assess the damage. Chief of Staff Toshiyuki Yokoi suggested to Vice Admiral Ugaki that he suspend all activity in order to preserve the few forces left.

Ugaki, however, decided to go for a knockout blow. At 8:10 a.m. on Wednesday, March 21, reconnaissance airplanes reported sighting two groups of U.S. warships only 320 miles off Kyushu. One of the groups included two aircraft carriers, apparently with no airplanes flying cover over them. The weather was clear. Ugaki and his staff reasoned that the carriers must have been damaged in an earlier Japanese attack and that there would never be a better opportunity to finish them off. He again ordered the Thunder Gods Corps to prepare for an attack.



There was tremendous excitement in the underground operations room of the Fifth Naval Air Fleet. Okamura worried about the few cover airplanes available for the mission. Yokoi nodded his understanding, then turned to Ugaki. "Sir, shall we wait for another chance?" he asked. The normally outspoken Nonaka remained silent, looking grim.

Ugaki stood up slowly, a determined look on his face. He faced Okamura directly. "If we can't use the Ohkas in this situation, we will never have the chance to use them," he said.

Okamura knew from the resolute tone of the vice admiral's voice that there was nothing he could do. It was the most difficult thing he had done in his life, but he finally managed to say, "All right, sir. We'll do it."

The final decision made, Wing Commander Kunihiro Iwaki and Nonaka left the operations room and headed for the airfield. There was a slight breeze rustling the leaves of the bamboo trees on the hillside. Walking a few steps ahead of Iwaki, Nonaka was deep in thought, pondering the life and death of the Kusunoki Masashige, whose words adorned one of his banners. Finally he turned to Iwaki. "Wing Commander," he said, "there comes a time when things are so hopeless that even warriors have to die."

Nonaka selected the best pilots in his squadron for the mission, dividing the 18 into six groups of three. Fifteen were to carry Thunder Gods and their Ohka bombs.

The 15 Thunder Gods and the mother airplane crews took clippings from their fingernails and hair and placed them in unpainted wooden funeral boxes for delivery to their parents. They took off their old clothes and burned them, putting on new uniforms. They then sat down and carefully wrote out their death statements. "My body will collapse like a falling cherry blossom, but my soul will live and protect this land forever," wrote 23-year-old Reserve Sub-Lieutenant First Class Yuzuru Ogata. "Farewell. I am a glorious wild cherry blossom. I shall return to my mother's place and bloom!"

In front of the headquarters building, the Thunder Gods who had not been chosen for the mission were all preparing farewell cups of sake for their colleagues. Many of them appeared more pale and nervous than those who knew they were about to die.

One of them, carrying a tray of drinks across the flight line, passed in front of a Betty just as the pilot turned on the engines for the routine preflight check. He was sucked into the propeller, thrown high into the air, and killed instantly. The dead Thunder God was quickly removed from the runway, but word of the accident flashed around the field, straining even more the ominous mood.

A drumroll was sounded, the signal for the Thunder Gods and the crews of the mother airplanes to line up in front of the headquarters building. The 15 Ohka pilots were wearing headbands that had been inscribed with the words "Thunder Gods" by Admiral Toyoda. Each one also had a sword in a brocade sheath strapped to his waist.

Nonaka, the overall leader of the mission, was wearing a white muffler. He unceremoniously sat down in a chair, holding his saber like a cane, with its tip resting on the tarmac. Beside him a large blue and white streamer and his two large banners flapped in the wind. The sky overhead was clear and blue. To the north were patches of white clouds. It was a beautiful early spring day.

The assembled men waited, growing more uneasy as each minute passed. Vice Admiral Ugaki was late. Finally he showed up, solemnly taking his place in front of the formation. Okamura was the first to speak, but it was hard to understand the commander because his voice was choked with tears.

"Today's mission will not be an easy one," he said. "But brave and resolute action will scatter even devils. With your passionate spirit of martyrdom, you will be able to overcome any kind of difficulty! You will succeed! Keep this conviction strong in your minds!"

Then Okamura's voice failed him completely. Tears flowed freely down his face, and he looked as though he were going to pieces. He struggled to continue.

"Looking back, your serene state of mind and outstanding behavior since last November has impressed me. I could not be more proud of you. Now you will go into the next world. And just as you have been in this world, I pray that you will continue to be pure, beautiful, healthy, and cheerful. Your colleagues and I will soon be following you. Please remember the ties we had in this world!"

Ugaki, Okamura, and the other officers exchanged farewell cups of sake with the Ohka pilots and Betty crewmen.

The fighters had been pulled out of their shelters and were now on line. The ground crews began warming up the Bettys. Their whirling propellers glistened in the sun, and the roar of

their engines filled the air.

Nonaka stalked to the front of the formation and turned to face the men. For several seconds he was silent, staring intently into each man's face. Then he said in his impressively loud voice: "We will now make an attack on the enemy's warships! Once you are in battle, do not hesitate. Attack aggressively and destroy your target regardless of all else. Let us fight to the death! Let us fill the Pacific with our blood!"

Nonaka turned to face Okamura, saluting him in his usual brusque fashion. "We go, Commander!" he said. Okamura returned his salute, his face drained of color.

Nonaka turned and signalled the men to break ranks and man their airplanes. The white flag went down. The roar from the airplanes' engines drowned out everything else. The Bettys, their heavy Ohka bombs suspended from their bellies, lumbered down the runway like fat gooney birds. As soon as they were in the air, the fighters began taking off.

As they turned to the east, the two squadrons were joined by a third squadron of 23 assisting fighters that had taken off from adjoining Kasanbara Air Base. The group headed southeast. Seven months after the Ohka program was first proposed, the Thunder Gods were making their first sortie.

About half an hour later, half of the fighters returned to base with malfunctioning fuel pumps. Because there hadn't been enough time to service the fighters properly, they hadn't been able to draw fuel from their second tanks. The shock to those waiting at the airfield was considerable. But more was to come. Most of the airplanes that had taken off from Kasanbara had the same problem and had to return. Only 30 fighters were left to cover the entire mission.

To make things worse, a reconnaissance airplane flying ahead of the Thunder Gods radioed back that three groups of American ships were in the area, with three aircraft carriers in one group and two each in the others. Not only was the force much stronger than previously believed, each group was sure to have covering airplanes.

There had been no word over the radio at all from Nonaka. It had been agreed beforehand that he and his squadron would maintain complete radio silence throughout the mission, but now the waiting was almost unbearable.

Several members of the Fifth Naval Air Fleet staff wanted to scrap the mission and call Nonaka back. But Ugaki, waiting in the operations room, refused. "The Thunder Gods are right now face to face with the enemy," he said. "I cannot bring those young boys back now after they have made up their minds to die. It would be too much for them to bear."

It was then approaching 3 p.m., well after the time the mission should have reached the target area. Still there was no word from Nonaka. If the airplanes were still in the air, their fuel would soon be gone.

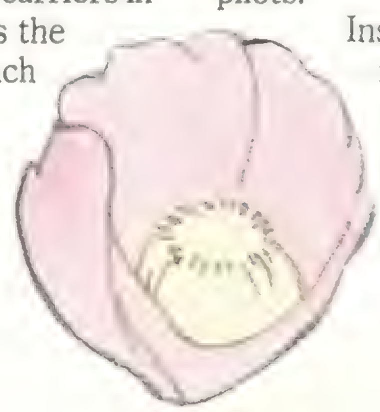
The air in the underground operations room was stale. The men sat around in silence, not trusting themselves to speak.

Just after dark, guards outside the tunnel reported the sound of an approaching airplane. A badly damaged Zero came in low from the bay and made a rough landing. It was followed by a second airplane. Both were pockmarked with bullet holes and streaked with oil. The pilots were exhausted, but between them they managed to tell what had happened to Nonaka's squadron.

At about 2:20 p.m., when the squadron was some 50 to 60 miles from the U.S. fleet, it was suddenly attacked by about 50 American fighters. The 30 Japanese cover fighters fought back, but nine Bettys and two special-attack bombers were shot down in just over 10 minutes.

Unable to match the enemy in number or firepower, the 19 remaining fighters dispersed. Left unprotected, the mother airplanes jettisoned their unmanned Ohkas, dispersed, and began battling to save themselves. Within 10 minutes, the only airplanes surviving were Nonaka's and three others. When one of the Zero pilots last saw them, the four were diving wing to wing toward the sea.

Altogether, 160 men had been lost, including the 15 Ohka pilots.



Inside the underground communications room, the radio man refused to turn his sets off, listening in vain for some final word from Nonaka. Outside, as searchlights swept the still dark sky, Nonaka's HI-RI-HO-KEN-TEN banner fluttered quietly in the night breeze.

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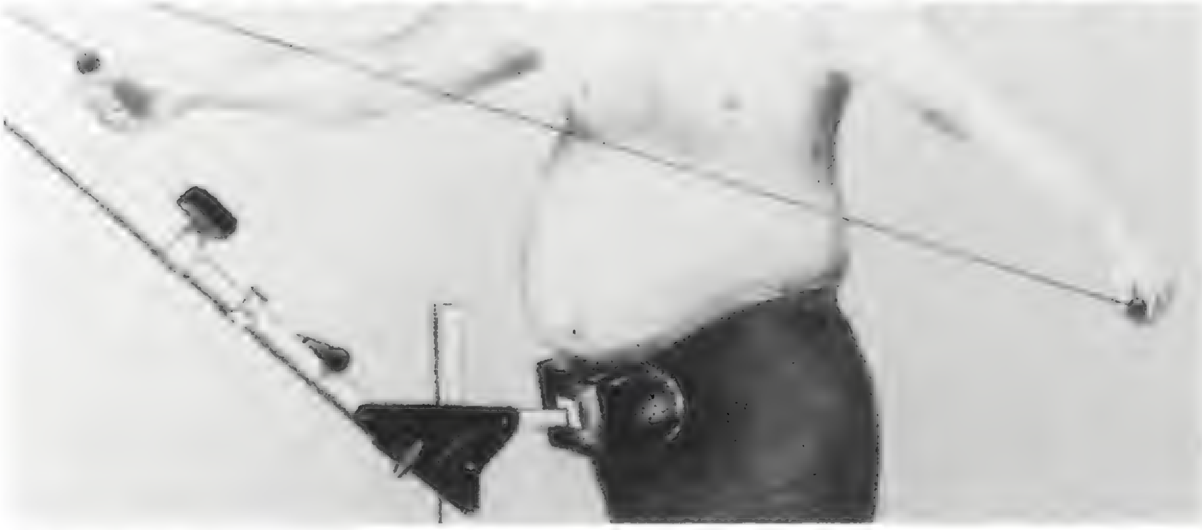

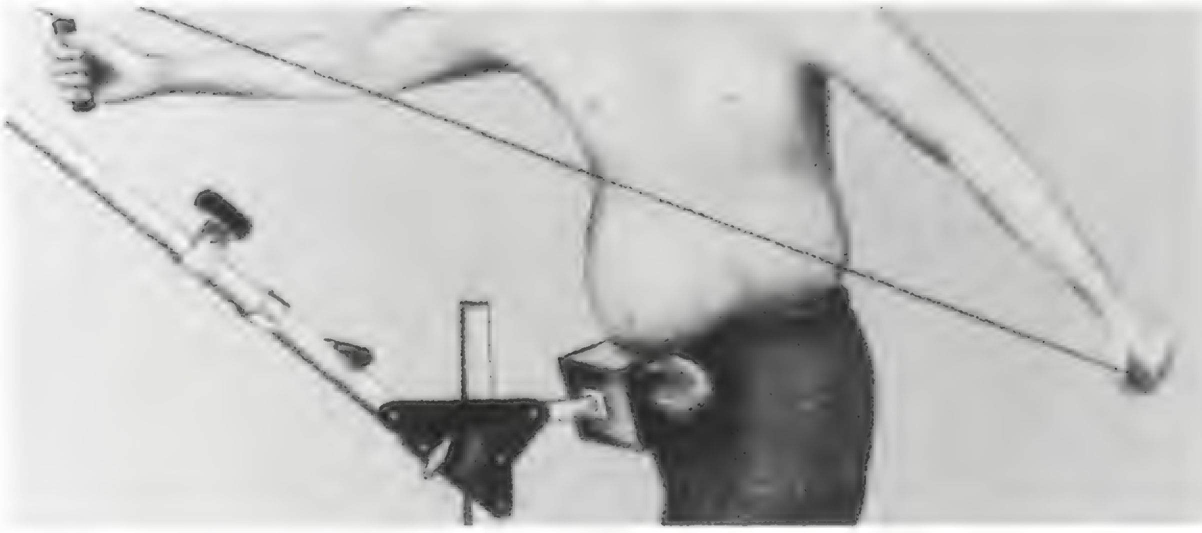

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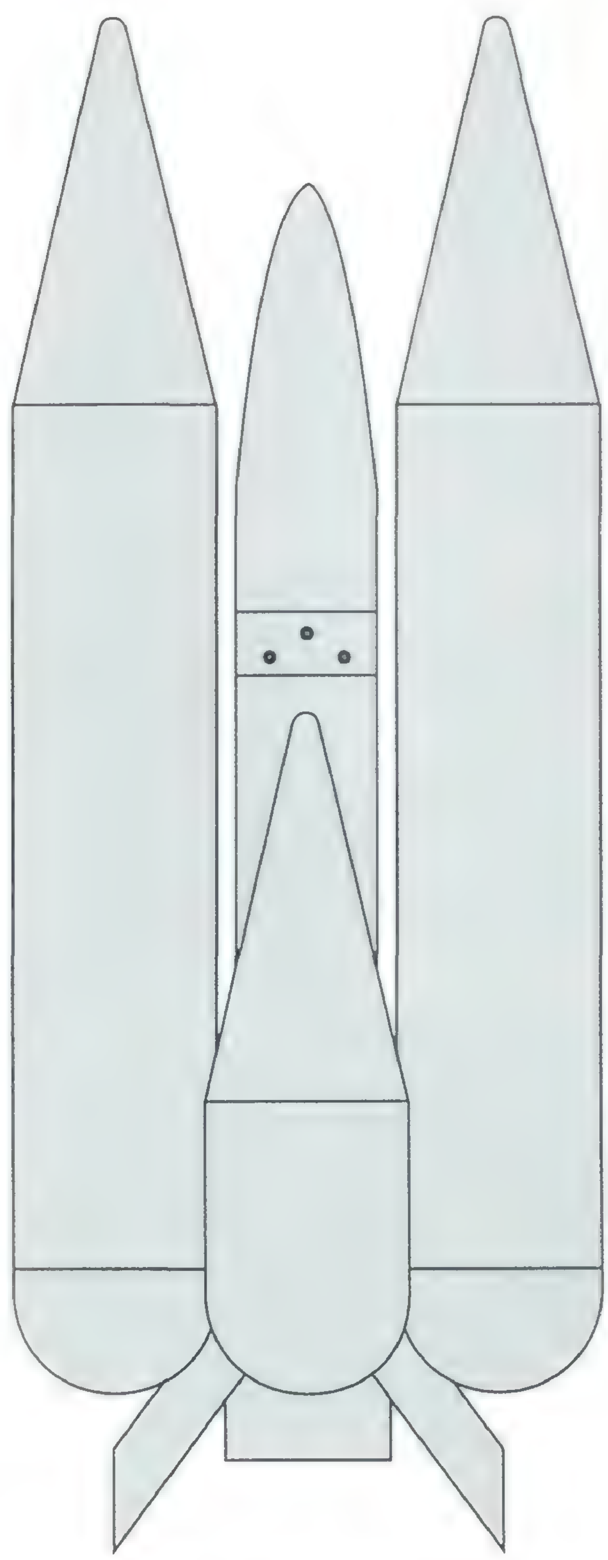
The Space Shuttle's Family Tree

Its roots can be found in hundreds of paper studies, experiments, and flying hardware.

by Richard P. Hallion

There was no clear moment, no major national address by the president, that set the shuttle program in motion. When NASA first detailed engineers to develop a real shuttle, it did so decisively. So decisively, in fact, that for some the decision came as a total surprise.

In early 1969, George Mueller, NASA associate administrator for manned spaceflight, gathered some engineers together for a meeting. One of them was LeRoy E. Day, who at the time was working on the Apollo program. Day recalls that when he arrived at the meeting, Mueller was discussing what would be required to develop a shuttle program. Day figured Mueller hadn't yet reached the Apollo matters he wanted to discuss with him. Instead, Mueller asked Day to join the shuttle effort. Day remembers saying that he could set to work "in a couple of weeks, right after this [Apollo 11] flight readiness review. 'No,' Mueller said, 'you don't understand. You don't understand. I want you over here now to begin work on the shuttle.' I said, 'What does *now* mean?' He said, 'Tomorrow morning.' " If any single event can be identified as the formal beginning of the shuttle program, this was it.



McDonnell Douglas, 1.5 stage, parallel tanks

NASA, the Department of Defense, and the U.S. aerospace industry can all claim credit for developing the space shuttle. Virtually all players were intensely involved throughout development in almost every technical issue. Aerospace companies, working two different contracts, offered their configurations to both NASA and the defense department, and many of the generic shapes they used had been developed at research centers such as the Air Force's Flight Dynamics Laboratory and NASA's Manned Spacecraft Center.

NASA's civilian space applications aimed toward designs with low lift-to-drag ratios, such as capsules and lifting bodies (see "The Legacy of the Lifting Body," p. 50). The Air Force's missions demanded higher lift—a more "flyable" spacecraft—and therefore shapes incorporating wings. Throughout the 1960s, both camps eyed the possibilities of winged boosters lofting lifting body orbiters.

Spinoffs of the B-70 and the X-20A Dyna-Soar programs, as well as a resurrected X-15, were considered, only to die at the paper stage while Apollo devoured the hardware funds. Even a single-stage "aerospaceplane" was proposed, and although Congress killed it in 1964, it fed more elaborate two-stage concepts such as the Martin Astrorocket, a winged booster-orbiter combination that would take off vertically. During the entire period of Air Force and NASA research, the government furnished the basic shapes (forged by such successful experiments as the ASSET and PRIME flights), leaving it to industry to add detail and fill in the blanks.

One example of the process at work was Lockheed's development of the 8MX, a shape designed by the Flight Dynamics Laboratory, into a complete shuttle system consisting of a stage-and-a-half winged orbiter flanked by two fuel tanks. NASA also received a similar

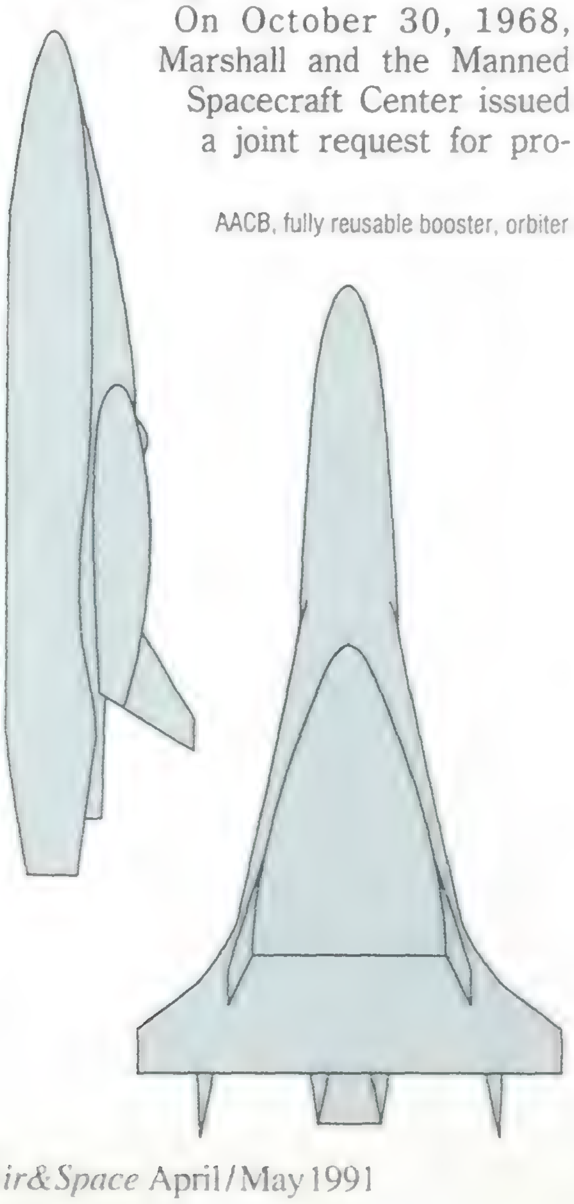
Adapted from The Hypersonic Revolution, Volume II, *edited by Richard P. Hallion, Wright-Patterson Air Force Base, 1987.*

proposal from Lockheed, this time as the Star Clipper. The most noteworthy idea in both concepts was the introduction of a partially expendable system (the fuel tank was discarded), along with the notion of housing a heavy payload within a large bay—much like today's shuttle. McDonnell Douglas submitted a similar vehicle, with tanks clustering around the orbiter.

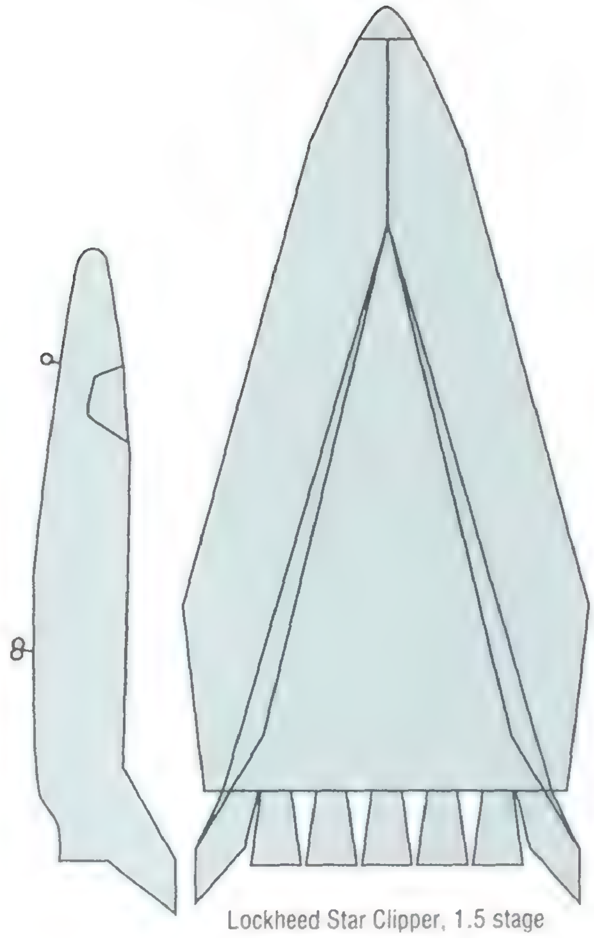
As late as the mid-1960s, the joint NASA-DoD Aeronautics and Astronautics Coordinating Board still had not been able to satisfy both the Air Force and NASA with a single configuration, but it did manage to endorse a partially reusable vehicle as more economical than fully reusable two-stage systems. But ideas for fully reusable systems persisted even after the board's September 1966 report.

After the Apollo program was under way, NASA began to consider an orbiting space station and, ultimately, a mission to Mars. These plans would require a shuttle to travel back and forth to the space station, and both Marshall Space Flight Center in Alabama and the Manned Spacecraft Center (now Johnson Space Center) in Houston had been studying such a vehicle while watching Air Force progress.

On October 30, 1968, Marshall and the Manned Spacecraft Center issued a joint request for pro-



AACB, fully reusable booster, orbiter

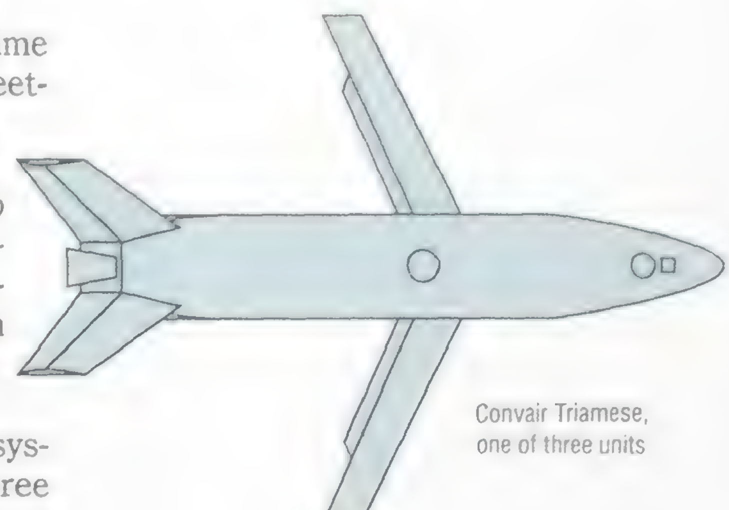


Lockheed Star Clipper, 1.5 stage

posal to study an Integral Launch and Reentry Vehicle System (ILRV) that could place 50,000-pound payloads into orbits at least 115 miles up. This marked the beginning of what later came to be called Phase A of the shuttle's development.

In February 1969, around the time LeRoy E. Day had his momentous meeting with George Mueller and Day's Space Shuttle Task Group was formed, NASA issued contracts to Lockheed, General Dynamics, McDonnell Douglas, and North American Rockwell for the ILRV study. In July, Day's group issued a report that expressed a marked preference for fully or near-fully reusable systems. The report envisioned three classes of vehicles, ranging from those with expendable boosters to fully reusable combinations, all designed to carry sections of space station measuring up to 15 by 60 feet. The group examined in detail a number of possibilities. Two were craft derived from the previous Lockheed and McDonnell Douglas studies for the Air Force, and a third was based on a lifting body design called the Manned Upper Reusable Payload. A pair of lifting body shapes based on Langley Research Center's HL-10 constituted a fourth design. An updated version of a design called Triamese that General Dynamics had earlier produced for the Air Force was a fifth, and NASA scientist Max Faget's design for a straight-wing orbiter was the sixth. Faget's design was eventually abandoned, but not before NASA examined it extensively enough to generate numerous spinoffs. This "00" series began to resemble today's shuttle orbiter with the sole exception of its wings.

During Phase A, both North American Rockwell and McDonnell Douglas closely studied the Faget concept. North American's version employed a Faget vehicle for both a reusable booster and the orbiter; McDonnell Douglas mated an HL-10 orbiter to a Faget booster. Lockheed championed its Star Clipper, and General Dynamics its Triamese and a new version called Biamese. Martin Marietta submitted an unsolicited design called the Spacemaster—a lifting body orbiter nestled between two parallel boosters joined by a stubby wing and tail surfaces. Although Phase A generated growing interest in a delta-winged orbiter, the Faget configuration was not finally eliminated until the joint NASA-Air Force body that came to be called



Convair Triamese, one of three units

the STS Committee (for "Space Transportation System") ruled that only a delta wing would be suitable for atmospheric reentry. Dale Myers, co-chair of the group and a NASA associate administrator, came from an aircraft design background at North American Rockwell and may have had a strong influence on the outcome. LeRoy Day recalls, "Dale was the one, I think, that really held the line and said, 'No, we're not going to go for this straight-wing business. We're going to go for the delta-wing vehicle.' "

Having decided on a delta-wing orbiter, NASA awarded Phase B contracts to McDonnell Douglas and North American Rockwell. At this time, the prevailing configuration still involved a large reusable booster that would fly back and

land on its own. Hedging its bets, NASA also awarded contracts extending Phase A to both Lockheed and a team formed by Grumman and Boeing.

Phase B was also extended into two follow-up studies called B prime (B′) and B double prime (B″). Throughout this period, NASA continued theoretical research it called the DC-3 Studies, after the Douglas airliner that had launched commercial airline transportation. As budgets tightened after Apollo, NASA came under increasing pressure. In 1971, the Office of Management and Budget froze NASA's annual funding at $3.2 billion. Because a fully reusable shuttle would cost $12 billion, such configurations were dead in the water. NASA would have to adopt a partially reusable shuttle.

At this critical juncture, it took Air Force support to keep the shuttle alive. With a seat on both the STS committee and Day's task group, the Air Force worked to influence shuttle design and make sure it had some utility for military missions. The service asked for a payload bay that measured 15 by 60 feet and could carry up to 65,000 pounds. In order to return to its point of origin after a single polar orbit, the shuttle would need a cross-range—the ability to fly some distance off its orbital track to land—of more than 1,100 miles, about equal to the distance Earth would rotate during a single shuttle orbit. The Phase B studies generated a series of designs NASA knew it couldn't afford, so it turned its attention to the

NASA Shuttle configuration 009-5

extended Phase A study conducted by Grumman and Boeing—the H-33, an orbiter that carried some of its fuel externally—and some in-house studies using external tanks. The orbiter would have a delta wing, but the rest was up for grabs.

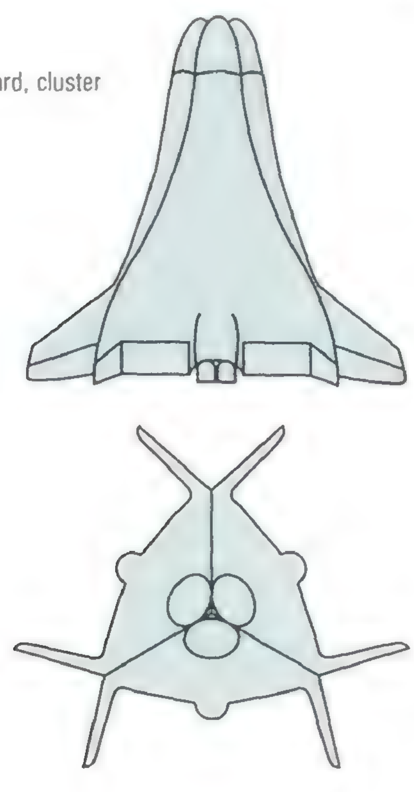
During this time, the Manned Spacecraft Center's design division produced a remarkable number of configuration studies, the most influential of which were the 036 and 040 series. The assumption throughout had been that the shuttle would use the Apollo's J-2 engines, and 036 had three J-2s and a payload bay of only 15 by 40 feet. The 040 configuration added a fourth engine in order to handle a larger, 60-foot payload bay. A hypothetical model 040C envisioned new high-pressure engines to cope with the higher payload weight, and although no such engines were anywhere near development, 040C defined what ultimately became the shuttle.

The idea of carrying hydrogen fuel in external tanks took hold in Phase B prime. By Phase B double prime, all boost propellants were moved to external tanks; now program costs could be kept within limits. While a new main engine was solicited from industry, NASA also wrestled with the mix of liquid and solid fuel in the booster stages. The Apollo F-1 and J-2 engines couldn't match the performance expected of newer designs and were eliminated from competition. A new Air Force solid-fuel booster with a 13-foot diameter seemed the likely candidate for the solid-fuel portion of the booster. And it could be recovered and refurbished.

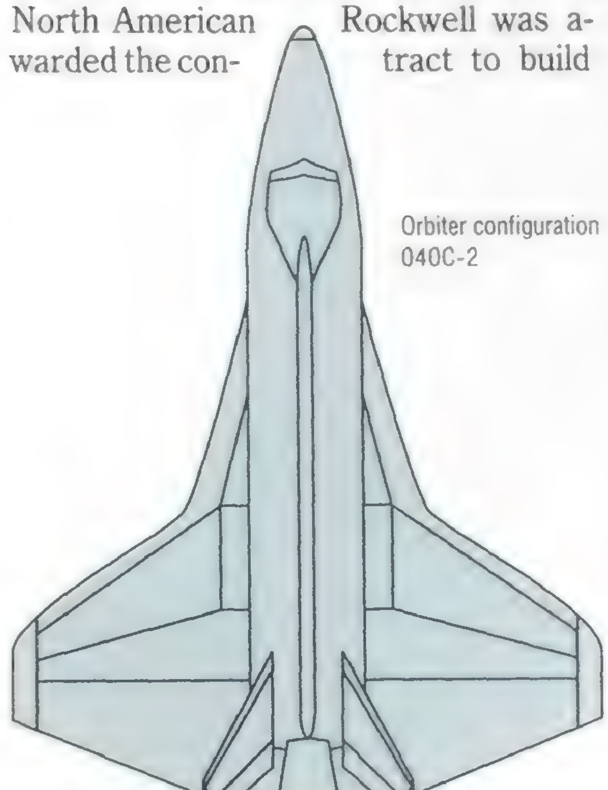
In the fall of 1971, the Office of Management and Budget asked NASA to evaluate a smaller shuttle, but NASA demonstrated that downscaling would have negligible effect on cost and take too big a toll on payload. With this final threat effectively parried and with more than $91 million already spent, on January 3, 1972, President Nixon approved continued development of the shuttle at an estimated cost of $6.2 billion.

North American Rockwell, Grumman, McDonnell Douglas, and Lockheed all submitted designs based on 040C for Phase C/D, development and production, and after intensive scrutiny by a blue-ribbon evaluation board, North American Rockwell was awarded the contract to build the space shuttle. Later, Morton Thiokol was assigned the solid-rocket boosters and Martin Marietta the external tank. Production began on June 4, 1974, and OV-101, a test vehicle named *Enterprise,* was completed in September 1976. After long delays in the development of the main engine and the surprisingly troublesome thermal protection tiles, the second orbiter, *Columbia,* was launched on April 12, 1981.

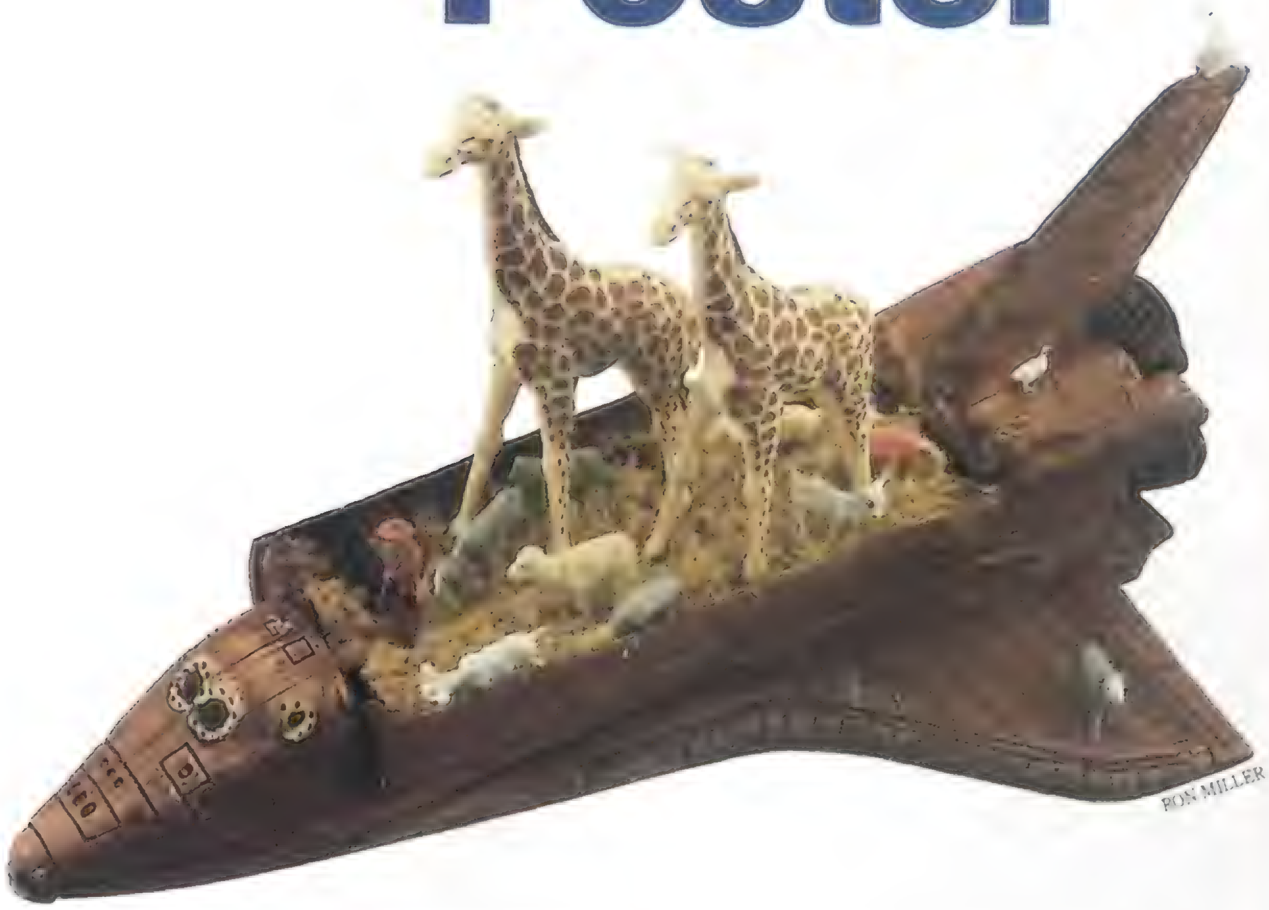
British Mustard, cluster



Orbiter configuration 040C-2



About the Poster



RON MILLER

ANDREAS NOTTEBOHM

On April 12, 1981, a winged spaceship named *Columbia* soared into space with astronauts John Young and Robert Crippen aboard. The flight of STS-1 ten years ago marked the first mission of the space transportation system, better known as the space shuttle.

The world's first reusable manned space vehicle, *Columbia* was soon joined by three others: *Challenger, Discovery,* and *Atlantis.* From their orbits above Earth, the shuttles have launched dozens of satellites, performed hundreds of scientific experiments, and carried out a variety of military missions.

Tragedy struck on STS-25 with the loss of *Challenger* and its seven crew members. In the years since, the program has suffered other setbacks, but overall the space shuttles have performed remarkably well. To commemorate the program's 10th anniversary, *Air & Space/Smithsonian* picture editor Lee Battaglia invited a number of artists to create their own space shuttles for a special poster.

Among the contributors are Robert McCall, Stephen Hickman, and four Soviet artists: Olga Kovaleva, Piotr Kovalev, Vitaly Myagkov, and Andrei Sokolov. Perhaps the artist with the most exotic credentials is Dave Pwerle Ross. An Aborigine from the eastern desert of central Australia, he painted a tribal legend on the shuttle. Other contributions were achieved with paint, sequins, glitter, glass, mirror, news clippings, postage stamps, even twine.

Air & Space/Smithsonian is also celebrating an anniversary—its fifth. The magazine's fate has always seemed somehow linked to the shuttle program, perhaps because our premiere issue, April/May 1986, went to the printer shortly after the *Challenger* tragedy, and the anxiety that always accompanies a magazine's debut became associated with questions about the United States' future in space. Today, five years later, we'd like to think that both will continue to hold your interest for a long time to come. Happy birthday, space shuttle—and happy birthday, *Air & Space.*

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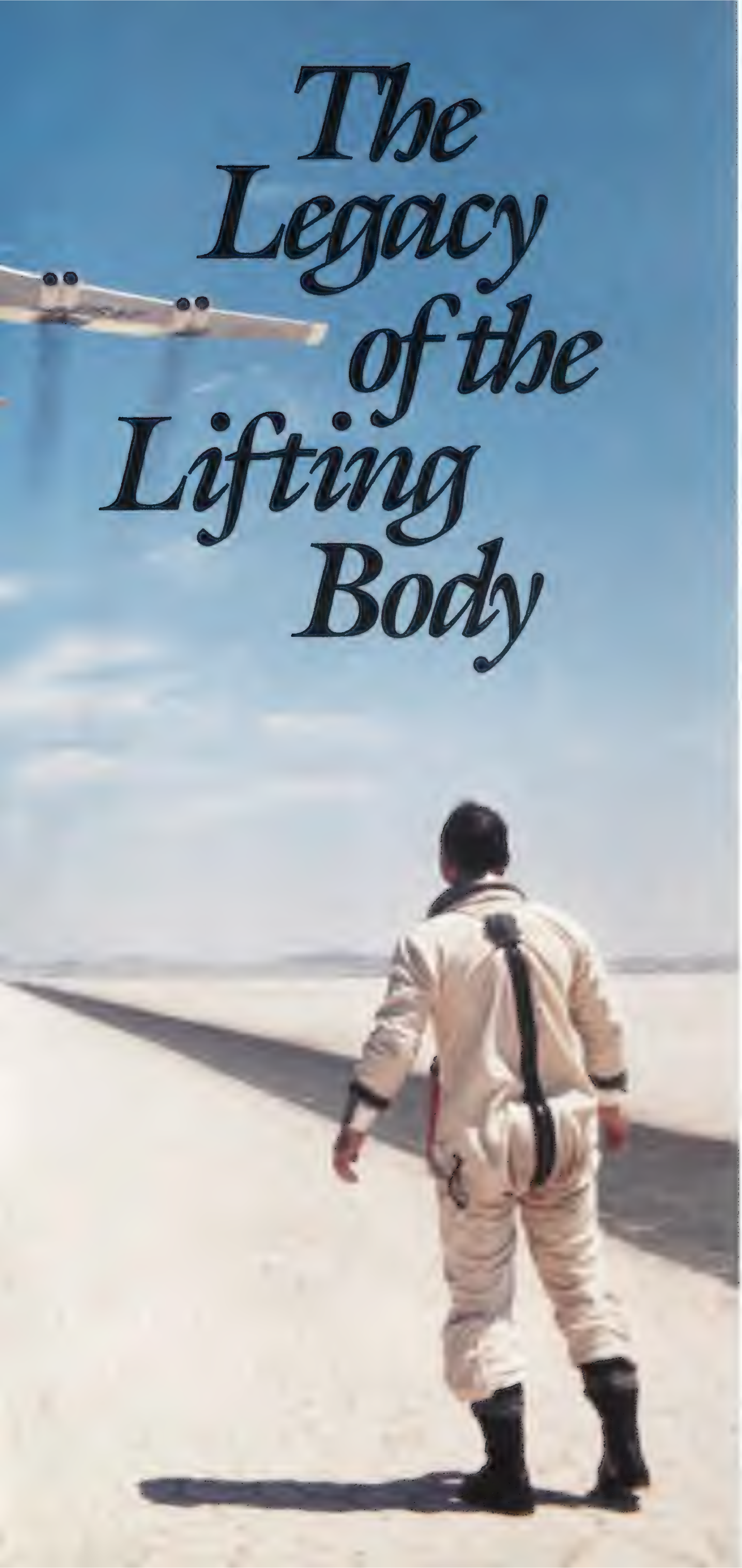
THE POWER IS ON


804
NASA

The Legacy of the Lifting Body



They may have flown like bricks, but these tubby, wingless aircraft helped pave the way for the space shuttle.

by Stephan Wilkinson

In the late 1960s, the rocket-powered X-15 spaceplane was flying at speeds approaching Mach 7 and altitudes that earned five of its pilots astronaut wings. The SR-71 Blackbird was operating at speeds and heights that no other air-breathing airplane has yet approached, and the swan-like XB-70 Valkyrie was routinely demonstrating that even transport-size darts could triple the Mach. There was even talk of an American SST.

It was the golden age of superplanes . . . and the hottest experimental program going was a fleet of what may have been the worst excuses for airplanes ever: the lifting bodies, wingless oxymorons that flew about as well as a kid's hand planing out a car window.

One was shaped like a household steam iron and had a glide to match. Another resembled a football gone soft, or a rubber duckie left in the bathtub too long. Yet another was made largely of wood, built by NASA for the cost of a Cessna. And the most infamous lifting body of all achieved immortality not by breaking barriers or notching new numbers but by crashing so horrendously that Hollywood used the footage to open each episode of the television series "The Six-Million Dollar Man."

Why on earth test wingless airplanes that maneuvered as handily as a Mack truck on ice? That had the glide angle of Wile E. Coyote going off a cliff? Simply to prove that it was possible to take an airplane that flew about as well as a cartoon villain and land it neatly.

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Above Edwards, NASA's B-52 shows pilot Bill Dana and his HL-10 lifting body how an airplane with wings flies.

Dale Reed (right) used radio-controlled models to show that a lifting body was feasible. The full-scale M2-F1 (left) came next. Made of little more than wood and steel tubing, it was towed in the air by a C-47 and on the ground by a Pontiac.

CHAD SLATTERY

NASA AMES

A lifting body is a wingless airplane that derives aerodynamic lift solely from the shape of its fuselage. The key word here is "solely." In the 1930s designer Vincent Burnelli did build odd airplanes with airfoil-shaped fuselages (see "The Burnelli Controversy," October/November 1989), which some claim were the original lifting bodies. However, no Burnelli could have flown without wings. Some aeronautical engineers also argue that a flying wing is a lifting body—not a wing without a fuselage but a fuselage shaped entirely like a wing. Let's leave that one to the semanticists.

The definition was also stretched to include the X-24B, an Air Force project with vestigial wings from the latter stages of lifting body research at California's Edwards Air Force Base in the mid-1970s. In all these cases, the shape providing lift was a "blended body"—it was hard to say where wing stopped and fuselage began.

The lifting body programs grew out of the space program. Both the United States and the Soviet Union, ostensibly racing to the moon, had concluded that the best way to bring astronauts home was in ballistic capsules that simply fell to earth. To engineers, that seemed "inelegant," their simplest and most descriptive putdown. The elegant solution, they felt, was a vehicle that could withstand the enormous forces and temperatures of hypersonic flight during reentry, then make the transition to supersonic and transonic speeds, yet still develop enough lift so that eventually it could go subsonic and maneuver to a controlled landing rather than an embarrassing plop in the ocean. Something like the space shuttle, in fact.

Easier said than done. As an airplane goes faster, its ideal shape changes, and wings increasingly become an impediment. The reason is simple: at high speeds, drag increases as the square of the increase in speed. Double your speed and you quadruple the drag; triple the speed and drag rises nine times. Wings, unfortunately, make not only lift but drag.

The most efficient airplane at low speeds is a sailplane, which has enormously long wings that lift it like a feather. The best competition sailplanes can descend almost imperceptibly, gliding forward 60 feet in still air for every foot of altitude they lose. The drag of those immense wings is considerable, but at sailplane speeds (as low as 70 mph) it's of little consequence.

How would you make a sailplane cruise at 300 mph? Put an engine on it, of course, and then shorten the wings considerably to reduce drag; you'd still get enough lift, thanks to the increased speed, to fly handily.

How about 1,000 mph? Use a bigger engine—lots bigger—then shorten the wings even more and sweep them way back for supersonic flight. Five thousand miles an hour? Remove the wings entirely—just saw them right off at the roots, thanks—and reshape the fuselage slightly so you get a little bit of lift, like the hand out the car window, at enormous speeds. Have you just invented the lifting body? Not quite, for you still need to make that 5,000-mph shape flyable at, say, 200 mph, so you can slow enough to land.

Around 1960, NASA-Ames Laboratory engineer Alfred J. Eggers came up with something he felt could do it: a shape like a badminton shuttlecock sliced in half lengthwise, the resulting flat side up, with a pair of vertical fins providing longitudinal stability. But it was only theory—and theory that NASA management wouldn't buy, for they felt Eggers' flying ice cream cone might glide a bit, but it certainly wouldn't be controllable on landing.

At that point, sailplane pilot, model builder, and engineer Robert Dale Reed, stationed at NASA's Dryden Flight Research Center at Edwards, got lifting body religion. He caused lots of eye-rolling and circling-finger-at-temple motions at Dryden, where he launched countless paper lifting body gliders down the halls. A serious radio-control modeler on the side, Reed initiated his very own miniature flight test program in February 1962. "I towed my first lifting body behind a gas model at a friend's ranch outside Lancaster," he recalls. "Had my wife lie on her stomach, so it would look more realistic, and do a little eight-millimeter movie. It showed how stable it was on tow, and we had a timer on the model that released the lifting body, and it glided down and landed."

Armed with the movie, Reed went to his boss, Dryden director Paul Bikle, with a proposal to build a full-size flight test version. "Bikle was hard to convince," Reed recalls, "until we got a test pilot, Milt Thompson, interested too." Thompson had been part of the X-15 program and had flown that spaceplane to 3,700 mph and 214,000 feet for NASA. "I asked Milt if he'd be willing to fly this thing and he said sure. He was really an adventuresome guy in those days, and having a test pilot's support was what really sold it."

Still, NASA wasn't about to commit serious money to this loony tune, so

Bikle and Reed, both talented scroungers, put together a hidden lifting body program, fueled with petty cash and reserves of voluntarism among the Dryden staff. "It was a real shoestring operation. We didn't get any money from anybody," Bikle boasted shortly before his death in January. "We just built it out of money we were supposed to use to maintain the facility."

What they came up with was the M2-F1, the first airplane actually built by NASA rather than a contractor and by far the cheapest flight article the agency had ever been involved with. "The entire program cost less than $30,000," Bikle said.

Dryden's small coterie of homebuilders, mostly Experimental Aircraft Association members who assembled their own sportplanes, volunteered to build the M2-F1's steel tube frame, cockpit, control surfaces, and landing gear at night and on weekends, behind a curtain in a corner of NASA's hangar at Edwards. Meanwhile, Bikle engaged a local glider builder, Gus Briegleb, to create the outer structure, a plywood lifting body shape based on Al Eggers' half-cone design.

"We knew we weren't going to be able to sell it to NASA headquarters as a manned airplane," Reed admits, "so we decided to build it so it could fly, put a cockpit in it, but the original justification was solely as a full-scale wind tunnel model."

Pinching pennies even tighter, the team recruited Milt Thompson to sit in the cockpit and work the -F1's controls during the tests at NASA's huge 40- by 80-foot wind tunnel at Ames, near San Francisco. (Aircraft are normally remote-controlled from outside the tunnel during such tests.) Was Milt game? You bet. "I tried to get them to attach a rope to it and let me actually try to fly it in the tunnel, but they wouldn't go along with that," he says. "They were afraid the rope might break and I'd disappear down the tunnel."

When it did actually fly, the -F1 was first towed behind a very special NASA vehicle: a straight-piped Pontiac convertible that had been modified by drag racer Mickey Thompson so it could run a consistent 140 mph. This hot-rodded muscle car was tuned for maximum torque at 100 mph, which had been calculated as the M2-F1's liftoff speed.

Painted with NASA colors and logos and sporting government plates, the car was pulled over by the California Highway Patrol on the trip back to Edwards from Thompson's famous Los Angeles shop. The CHiP couldn't restrain his curiosity: What in the world did NASA want with a ragtop with a roll bar and race car tires? (When the Pontiac was sent to another NASA division at the conclusion of the M2-F1 program in 1963, some engineers were sorry to see it go. "No longer can we drive along the lake bed and pass the airplanes in flight," one said.)

After the muscle car, the -F1 graduated to a Gooneybird, an aging NASA C-47 that would tow it to 10,000 feet. Also brought into the program was Air Force test pilot Jerauld Gentry, who found flying the -F1 on tow to be a challenge. Once at altitude, the little white lifting body would be released from its 1,000-foot cable. Gentry was then supposed to put the nose down and sink rapidly to a landing on the lake bed at an adequate but not ideal glide speed of 120 mph.

But Gentry, a fighter pilot who went on to make the first flight of the Air Force's X-24A lifting body and then flew in Vietnam, never mastered the arcane skill of flying on tow and was too short to see well out of the -F1's cockpit. Soon after the -F1 and the C-47 left the ground, Gentry lost sight of the horizon and sank into the towplane's propwash. "Our observer in the little navigator's dome on the C-47 saw Gentry get into a rocking motion," Reed recalls. "It got bigger and bigger, and he went all the way over the top. The last thing our guy saw was the lifting body upside down, disappearing out of sight below the C-47. When they turned back toward the lake bed, he expected to see the M2-F1 scattered all over the lake bed, which could have been the end of the entire lifting body program."

"Oh, hell, I was upside down twice on tow," Gentry recalls with a laugh. "As soon as I could figure out which way the roll was going, I put stick in with the roll and went on around. When I got momentarily to wings-level, I punched off. Barely had time to release the tow, flare, and *whump*. The second time it

At Langley Research Center, engineers put an HL-10 model through its wind tunnel paces.

Dryden director Paul Bikle (below) oversaw one of the thriftiest programs NASA ever handled.


CHAD SLATTERY

NASA LANGLEY

happened, I said, 'Well, I've been here before.' I'd gotten good enough at it that I even glided for a few seconds."

Through with pushing its luck, NASA at that point grounded the -F1 forever, having proved, in nearly 100 flights by 10 different pilots, that a wingless, feather-light wooden airplane shaped like a piece of pumpkin pie could fly and land. In fact, flying the -F1 had become a task that was mostly undertaken as a final exam for pilots ready to check out in its heavyweight successor.

The all-metal M2-F2 weighed nearly six times more than the -F1, had provisions for installation of a rocket engine to power it to Mach 2, and was dropped by a B-52 at 45,000 feet.

"There were fears that we might fly back up into the B-52 after separation from the pylon," says Gentry, one of four pilots who flew the -F2. "Lemme tell ya something, there was no question which way you were going when the B-52 dropped you. One guy used to say that if they dropped a brick out of the B-52 at the same time I released, I'd beat the brick to the ground."

The M2-F2 and the subsequent HL-10, a heavyweight lifting body designed by NASA's Langley Laboratory, were both built by Northrop. The programs were characterized by a lack of bureaucracy rare in the aerospace industry. "At that time, Northrop was a totally different company," says Dale Reed. "It wouldn't work today. They ran a little airline using Piaggio twins, and I had a team of engineers I'd take every day down to Northrop and work right with them. We were authorized to make decisions right on the spot."

One of those decisions would have fortunate consequences for a NASA test pilot named Bruce Peterson. "Lifting bodies tended to get tail-heavy, the way the airframe is shaped, so we had to put weight in the nose of the -F2," Reed explains. "One of us—I don't even remember whether it was a NASA or Northrop guy—said, 'Let's do something useful, like putting extra structure around the pilot.' We all jumped at that, and instead of a 50-G cockpit we made it about a 300-G cockpit, with a real heavy steel frame around the pilot."

NASA AMES

Bruce Peterson's problems stemmed from a near-fatal flaw in the heavyweight lifting bodies: their tubby, upswept bellies were the equivalent of a set of wings with extreme dihedral (the angle at which the wings are built from the horizontal). When an airplane banks, its dihedral tries to correct the movement and right the ship. When the M2-F2 banked in one direction, its dihedral also tended to create an ill-tempered yaw in the opposite direction—a tendency that on conventional airplanes is mitigated by an effective vertical fin (or fins). In certain flight attitudes, however, the stabilizing vertical fins were blanketed by huge vortices of air that spilled and rolled up and off the sides of the bellies. (Lifting bodies make lift the same way an ordinary airfoil does: a low-pressure area is created above the vehicle because the air flowing over it must move faster to reach the trailing edge at the same time that the underflowing air does. On a conventional airfoil, this is largely a simple, two-dimensional, front-to-rear process except at the wingtips, where some air spills sideways, up, and aft in a more complex three-dimensional flow, creating what are called tip vortices. A lifting body, however, is virtually all "wingtip"; very little lift-inducing air flows linearly, and most of it creates complex, drag-inducing tornados of roiling air.)

The result was self-perpetuating roll coupling, in part because of the airplane's inherent instability and in part because the pilot's attempts to fight it were self-defeating. Like an inept driver yanking the steering wheel back and forth in a skid, each correction the pilot made was a split second too late and out of phase with what the airplane was actually doing, serving only to increase the next roll/yaw movement in the opposite direction. It's called "PIO": pilot-induced oscillation.

"I got into a very violent PIO on the first flight [of the M2-F2], and it was partly my fault," Milt Thompson admits. "We had an interconnect between the ailerons and rudder that we could vary, and it increased or decreased the sensitivity to PIO. I turned it the wrong way just as I was turning final."

Films of the flight show Thompson's lifting body swinging from side to side like a cathedral bell in the hands of a hysterical ringer. Footage from an over-the-shoulder cockpit camera shows even more vividly how test pilots earn their pay. Through the windshield, the horizon rolls from vertical to vertical as fast as you can say it, yet Thompson's hand on the control stick moves no more than two inches from side to side, correcting subtly in a situation that would have an ordinary pilot sweeping the cockpit as though the stick were a broom.

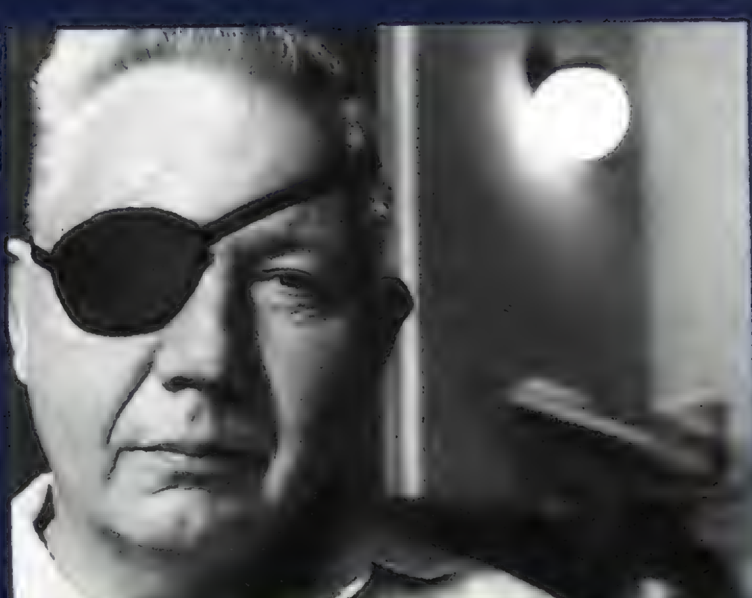
Peterson, another superb pilot—he'd managed an equally extreme runaway Dutch roll during the first flight of the HL-10—unfortunately made the same kind of mistake, forgetting to reset the aileron-rudder interconnect during what turned out to be the 16th and final flight of the -F2 on May 10, 1967. By the time he'd adroitly stabilized the ship, Peterson had drifted away from the runway markings on the Edwards lake bed. He was having a hard time judging his distance above the now-featureless flats, and to further complicate his life, a rescue helicopter seemed to be in his path. "Get that chopper out of

CHAD SLATTERY

Test pilot Milt Thompson joined the lifting body program early in the game and even offered to "fly" the M2-F1 in a wind tunnel. He later graduated to flying the -F1's successor, the heavyweight M2-F2 (left and below).

NASA AMES

CHAD SLATTERY



NASA AMES (2)

The M2-F2 (above) was a tricky bird to fly, as pilot Bruce Peterson found out on May 10, 1967. Peterson was badly injured when the craft crashed. The M2-F2 was brought back to the shop, reemerging improved as the M2-F3.

the way," he radioed. "That chopper's going to get me, I'm afraid . . . ."

What got Peterson, however, is that the distraction caused him to extend the fast-acting landing gear perhaps half a second too late. The M2-F2 hit the lake bed at over 250 mph with the gear half-down, bounced 80 feet into the air, then tumbled and rolled six times. When it came to rest the aircraft looked like a beer can after a Hell's Angels meeting.

"You couldn't even recognize that it had once been the M2," says Dale Reed, who was watching in horror on a TV monitor. "But the cockpit was intact. That extra-heavy structure we'd put in the nose had saved Bruce Peterson." But only barely, for it took repeated operations over 18 months to reconstruct his face alone, and though he eventually returned to flight status,

NASA AMES

he remains blind in one eye.

The wrecked M2-F2 went into Northrop's shop and came out, rebuilt, as the M2-F3. A third vertical fin, added for increased stability, made all the difference. "It turned from something I really did not enjoy flying at all into something that was quite pleasant to fly," says Gentry. And with that rebuild and the parallel successes of both the Langley-designed HL-10 (which already had a central vertical fin like the M2-F3's) and the Air Force's own X-24A, the lifting body program proved that wingless vehicles returning from spaceflight altitudes could routinely be landed not only on huge lake beds but on runways, even if the best landing approach did turn out to be a steep, screaming, high-energy descent.

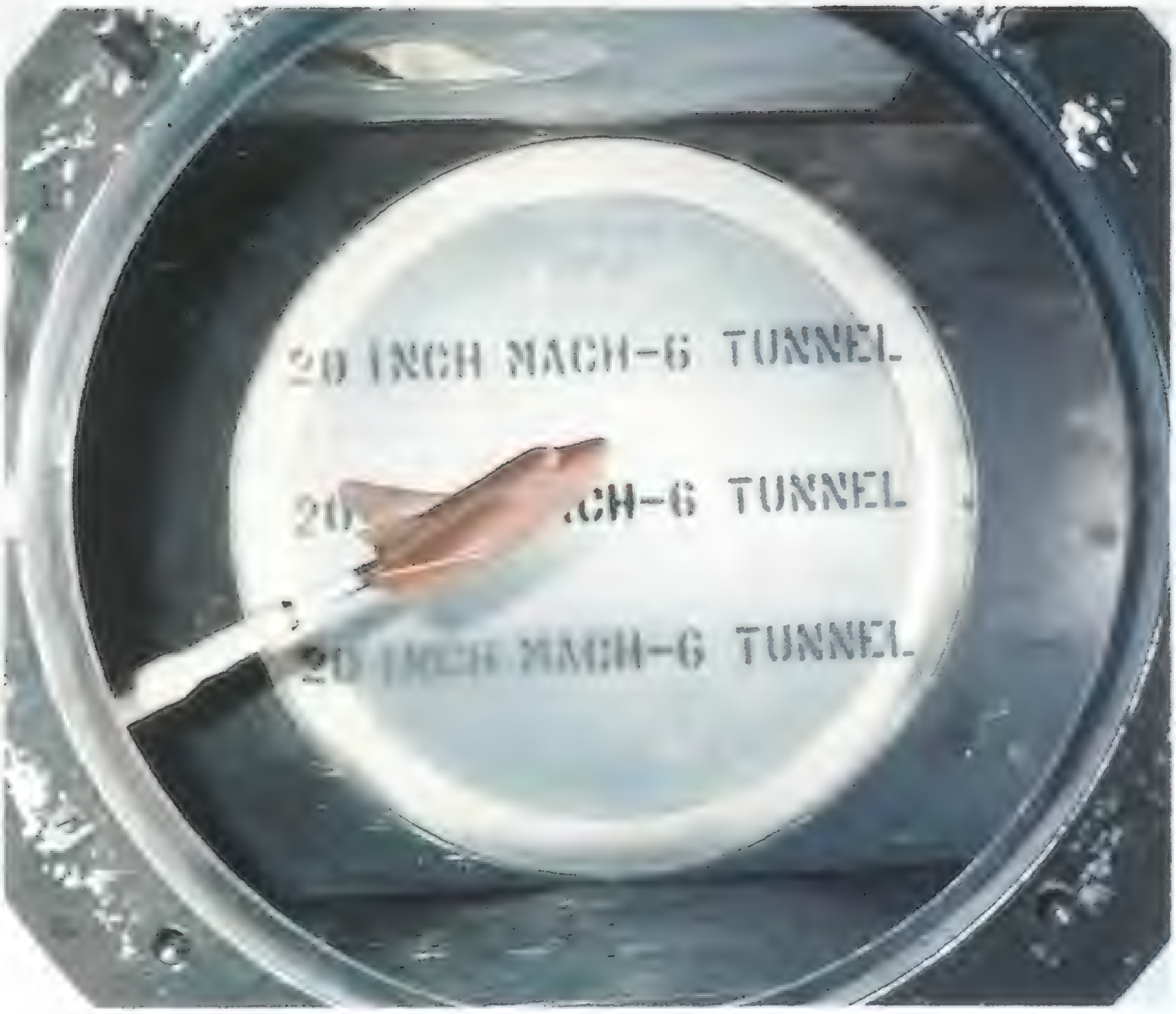
But when the Dryden lifting body team proudly went to NASA-Houston with film of its flight tests, Houston wasn't impressed. They were in the initial stages of designing what would eventually become the shuttle, and at that point Max Faget, NASA's preeminent spacecraft designer, favored a huge, eight-man Gemini capsule as the reentry vehicle. "We showed them our films," Thompson recalls, "and Faget said, 'Oh hell, that's just a stunt. You're using toy airplanes.' So I thought to myself, *Well goddamnit, we'll do it with a* big *aircraft and show 'em.*"

The Dryden gang needed something seriously huge to imitate a space shuttle, but nobody was about to build a 400,000-pound lifting body. Then one day, just as Jerry Gentry rolled the M2-F3 to a stop after being dropped from NASA's B-52, the elderly Boeing did a racketing low-level salute over the lifting body on the lake bed, eight smoky trails streaming out of the bomber's wailing engines. "He'd been at 45,000 feet just a few minutes ago," Gentry says. "It dawned on us: How'd he get down here so quick?"

The B-52 crew demonstrated: engines to flight idle, throw out the landing gear, pop the speed brakes, put the nose

BRETON LITTLEHALES

The Air Force conducted its own lifting body program with three X-24 aircraft. Test pilot Jerauld Gentry (right) flew for both the NASA and Air Force programs. He also flew upside down in the M2-F1, though not on purpose.



No longer just a thing of the past, the lifting body may be revived as the HL-20 space taxi (above). The National Aerospace Plane is also being designed along lifting body lines.

PETRACHENKO/NASA LANGLEY

down, and descend like Bullitt's Mustang coming down Telegraph Hill. So the lifting body pilots set out to prove they could spot-land something other than toy airplanes. Seeing a B-52 (as well as NASA's Convair 990 four-engine airliner, which was also recruited for the experiment) making like a dive-bomber was shocking. "It looked horrible from the ground, but once you'd tried it, it was a piece of cake to fly," says Thompson. "We became convinced that high-energy accuracy landings were possible not only in a lifting body but in something representative of what the shuttle might be."

Ultimately, that became the lifting body program's substantial but little-known legacy. "It made possible the acceptance of the operational mode and configuration of the space shuttle," Dale Reed says. "The initial shuttle design had pop-out engines [to aid in landing]." Reed recalls that the Houston engineers were cool to the idea of an unpowered airplane with such a rapid rate of descent: " 'Totally ridiculous,' they said. 'Too dangerous.' When we started getting routine success with the lifting bodies, after we'd cured the initial control problems, they began to accept it, and it made for a much more practical shuttle, because you had very little payload left after you put heavy jet engines and fuel on it."

For a while there was even talk of the space shuttle being configured as a true lifting body, but two factors made that impossible. As the Department of Defense became increasingly interested in the shuttle, the Air Force, knowing that wars don't wait for perfect weather, optimum launch windows, ideal retrieval times, or other NASA considerations, demanded greater landing flexibility than a pure lifting body could provide.

Even more problematic, however, was the fact that lifting bodies needed to be blended shapes—airfoils of a sort. Erecting a huge payload bay atop a lifting body would have spoiled its ability to lift, so such a shuttle wouldn't have been able to carry anything that didn't fit within the narrow constraints of aerodynamic blending.

But NASA hasn't given up on the lifting body quite yet. If the United States is ever to build the National Aerospace Plane—the Mach 25 NASP, the first version of which will be called the X-30—it will be a lifting body. That choice was officially affirmed last October, though a full go-ahead decision on the project won't be made until 1993. As one engineer put it, the NASP will be "nothing more or less than a flying inlet." And a lifting body shape seems to be the best way to deal with the horrendous problems of stuffing air into scramjet engines at hypersonic speeds without literally blowing out the fire.

Meanwhile, at Virginia's Langley Research Center, engineers have been studying a lifting body called the HL-20, essentially an orbital taxi that could be launched to the space station atop an expendable booster and returned to Earth with passengers or light cargo. Students at two North Carolina universities have even constructed a full-scale mockup of the craft.

The meter stopped running long ago for a similar concept dreamed up by the Northrop team in the 1970s. "We'd just finished the Apollo program, and we had four huge Saturn [booster] systems for which no use was specified," remembers Reed. "Wernher von Braun was out there at Dryden and I proposed to him launching two lifting body Saturn missions, carrying HL-10s in the same space where the lunar lander had been fitted. In the first, the astronauts would send the lifting body back unmanned and return in the capsule. If that was successful, on the second mission one of the three astronauts would come home in the lifting body."

Reed recalls that "von Braun thought it was a fantastic idea. He said to Bikle, 'I'll go ahead and prepare the rockets. You get the lifting bodies ready.' So here are two of my heros together in the same room, and we're about to come up with the first-ever lifting reentry, many, many years before the shuttle. It never happened, but here's two guys who worked outside the bureaucratic process, and they probably could have done it. That would have been neat. If we'd been able to keep the momentum of the lifting body program up, we could have taken it all the way. Taken it into space."

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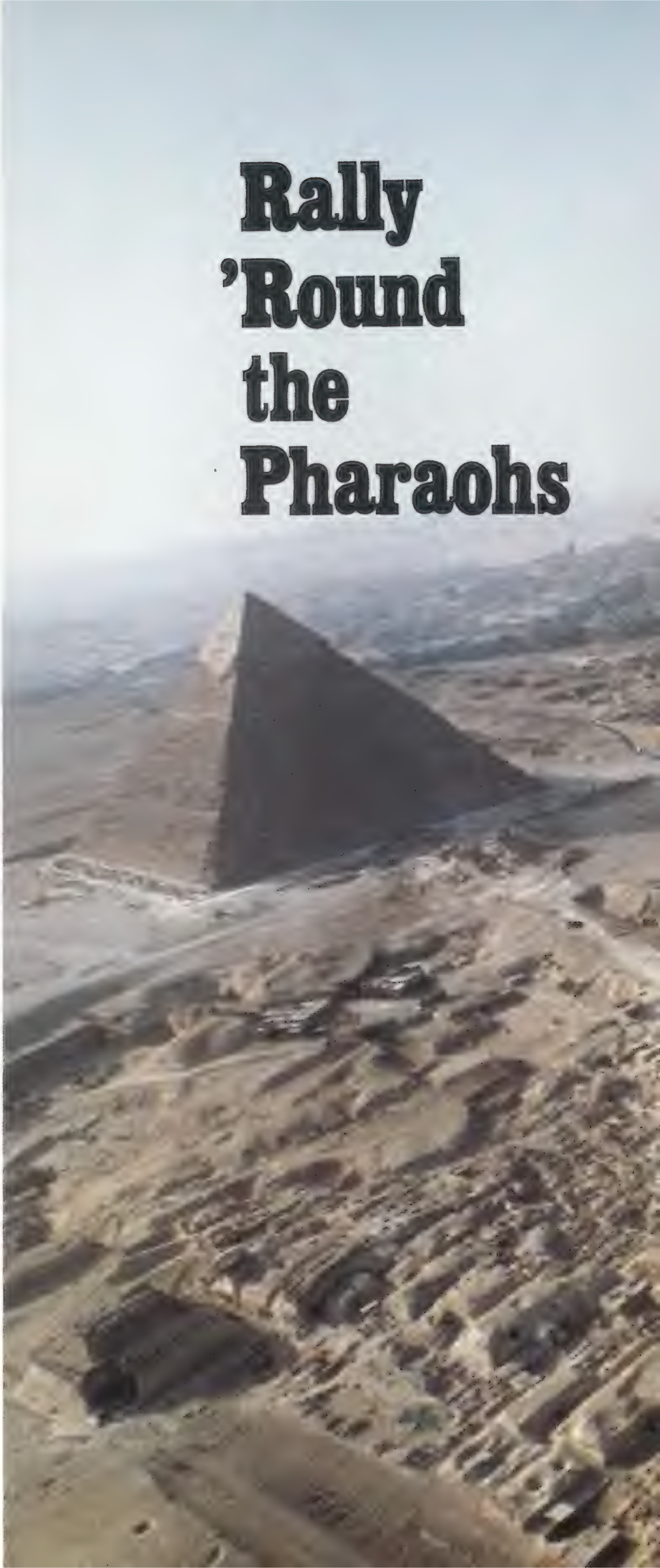


Rally 'Round the Pharaohs

by Anna Maryke

Photographs by Simon Chaput

Egypt is a country of sun, sand, camels, dogs, mules, long flowing robes, loosely bound *kaffiyehs*. And pyramids. The most famous, the Great Pyramid of Cheops built for the pharaoh Khufu, stands on the plains outside Cairo. On an October morning last year, some 1,200 people milled about its base, preparing for the start of an odyssey—a 3,000-mile cross-country race called Le Rallye des Pharaons.

Each year since 1982, the Rally of the Pharaohs has lured the world's top rally car drivers and champion motorcycle riders to an 11-day race across the spectacular Egyptian desert. Last year's race saw a novel addition. Seventeen ultralights—hang gliders with two-stroke engines—followed the same route as the cars and bikes, but 10 feet to 12,000 feet higher.

Overseen by France's Fenouil Organization, a sporting event promoter, the race was supported by commercial sponsors—Camel, Hotel Ibis, Loock Textile—whose names were splashed across the various vehicles. At considerable cost, participants provided their own manpower and equipment. Winners in each category could expect, along with the thrill of victory, potentially lucrative advertising opportunities.

My role in our ultralight team, sponsored by Cosmos, a French ultralight manufacturer, was assistant to the photographer. The rest of the group, which has been flying and designing ultralights for years, consisted of eight pilots, three drivers, a mechanic, and a medic, manning six aircraft and three trucks with two-way radios.

Ultralight pilots sharpened their racer's edge around the pyramids of Giza.


COSMOS
COSMOS

Various modes of transport mingled outside Cairo at the start of the 3,000-mile race (left).

Bedding down in the Sahara, crews found that a good night's sleep was scarcer than water, food, and fuel (right).

The machines and crews that survived the grueling desert race neared the finish line with a gusto fueled by gratitude and relief (below).

The rally started at Cairo, roared south along the Nile, veered east to the Red Sea, turned inland to Luxor, Aswân, Lake Nasser, and Abu Simbel at the Sudanese border, headed northwest to Siwa, skirted Libya's border, dipped southeast to Ain Dalla, and returned to Cairo. Ultralights negotiating the sinuous route were rewarded with a bird's-eye view of Egypt's stark beauty—crocodiles along the Nile, mako sharks in the Red Sea, sub-sea-level lakes, the Ramses temple, the Sphinx, majestic pyramids, and the vast and barren Nile Sahara.

But for all the surrounding beauty, the race was primarily a struggle to beat the clock and the grueling environment. Battling rocky plateaus, gritty and erratic winds, sizzling temperatures, and a relentless sun, competitors on and off land raced to designated checkpoints, covering about 300 miles each day. Penalties accrued for miscalculations in distance, speed, time, and strategies.

Our number one problem was fuel: where to find it, how to strain out the impurities, how to store it. Upon arriving at Cairo, we learned that despite promises in the race's glossy brochures, there was no fuel on site. Fortunately there was a gas station nearby, but with the city's packed streets and chaotic traffic, it took 45 minutes to drive a half-mile. Once outside town, we spent many nights combing areas near campsites for a supplier.

Our number two problem was the terrain—shifting, sinking desert sand riddled with large stones. It was hardly suitable for takeoffs and landings in fragile craft. Often pilots could not gather enough speed to even break ground. Once airborne, they were grateful to land on

After crossing the finish line in second place, a Cosmos team ultralight took a victory spin around the Great Pyramid of Cheops (opposite).

This mishap occurred when the desert sand tripped up a takeoff (above left). The pilot walked away, but the airframe was totaled.

The Cosmos team captured first and second place but lost one car and three ultralights in the process (below).

the broad asphalt runways at military and civilian airports like those at Luxor and Abu Simbel, threading among airliners as instructed by the control towers.

Accurate flight planning, key to a winning strategy, was constantly frustrated by the erratic wind speed and direction. Mysterious engine sputterings and stoppages plagued us the first five days until we discovered that despite our straining the fuel through cotton, impurities were clogging the filters. Eventually our mechanic devised a double fuel feed system with two filters, which seemed to solve the problem. Engines regularly overheated in the 130-degree weather, and for that there was no solution but to land and let them cool. As far as creature comforts went, water was as scarce as fuel, and bedding down in the desert on compacted sand, we found that sleep, if it came at all, was fitful.

By day six we had stumbled along behind our racers as far as the Aswân High Dam, maintaining the top three slots in the race despite all the difficulties. Navigation was solely by compass and map, since there are no reference points or markers in the shifting dunes. Twice we had to lash a stricken ultralight onto the roof of a truck and drive it to the next checkpoint for repairs. Stocked with 2,500 pounds of equipment—spare parts, two-stroke oil, 60 gallons of water, and a few hundred gallons of fuel—we sped through remote areas dodging cats, cattle, trucks doing 125 mph, and kids who amused themselves by throwing stones at our windshield. However, we were among the more fortunate—we only got bogged down in the sand once.

By day seven many competitors—cars, bikes, and ultralights—had dropped out. We passed cars that had blown tires or were teetering on their roofs where they had run off the road. Bikes often succumbed to broken drive chains, and ultralights suffered torn wings or broken frames. During the course of the race the Citroen team alone replaced 73 transmissions. Each day a truck beetled along the course to pick up defunct vehicles and their drivers so that no one was left to fry in the sweltering sun.

By the last day of the race Le Rallye des Pharaons had taken on the characteristics of an Outward Bound session for motorized transport. Our team had lost one of its three support trucks and half its ultralights. Our one consolation was the sight of two of our remaining craft crossing the finish line at Cairo a few feet above the winning cars, capturing first and second place.

How to Succeed in Business Without Really Flying

Spacehab hasn't yet left the ground, but the commercial module has already won NASA's blessings.

by Frank Kuznik

Bob Citron's brainstorm started out simple: offer tourists a ride into space. "The original idea was for a module that would fit into the shuttle that could carry passengers," he recalls. "It would carry 32 tourist researchers who would go into space and help the scientists do their work on the space shuttle." The concept, dubbed Space Travel, was an outgrowth of one of Citron's earlier businesses—Earthwatch, an operation that provided laymen a chance to join scientific expeditions.

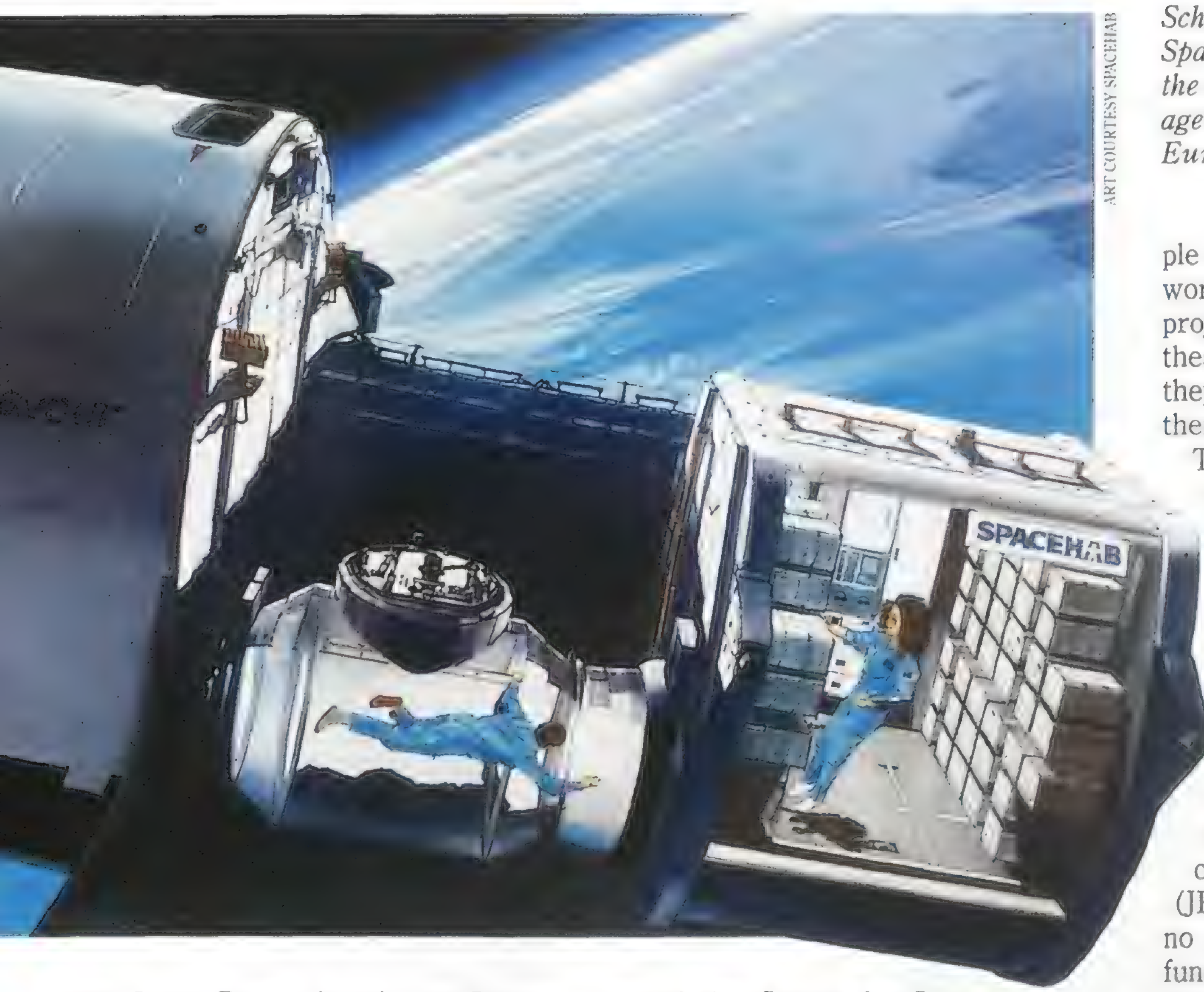
Citron had started and sold off other small businesses during the 1970s and early '80s. Before that, he had put in 18 years with the Smithsonian Institution establishing satellite tracking stations and a disaster-monitoring network. He also set up a lunar surveillance program for NASA during the Apollo missions. At heart, Citron was an entrepreneur who had never lost his childhood fascination with space travel. To his way of thinking, Space Travel was a natural.

Starting in 1983 with $25,000 of his own money, Citron began to shop the scheme around. His first stop was NASA headquarters, where he sought out Chester Lee, the man responsible for manifesting shuttle payloads. NASA, it turned out, wasn't interested in tourists, but Lee found the idea of increasing the shuttle's workspace immensely appealing. "Being in the manifesting area, I could see we were going to develop a backlog of R&D testing," he remembers. "So my counterpart [at Johnson Space Center] in Houston and I were saying, 'Hey, we better think about adding something'—and then here comes Citron with something that fit the bill." Citron's module, positioned in the shuttle's cargo bay, could be used as a pressurized laboratory for industrial experiments. To tend to the experiments, the crew would simply float out of the mid-deck and enter the lab through a connecting tunnel.

Lee became a true believer: today he is executive vice president of Spacehab, Inc., the company that is shepherding Citron's module through NASA's contracting maze. And Lee wasn't the only one to transfer his NASA experience to the Spacehab effort: James Ball, a public affairs officer in NASA's office of commercial programs, left the agency to become the company's marketing director, and former NASA adminis-

SPACEHAB

Bob Citron enlisted astronauts Owen Garriott (left) and Byron Lichtenberg to help develop Spacehab. Other NASA veterans later joined the effort.



ART COURTESY SPACEHAB

Scheduled to start flying in early 1993, Spacehab will carry experiments for the Canadian government, space agencies in Virginia and Florida, a European consortium, and others.

trator James Beggs signed on as Spacehab's chairman of the board. Serving as Spacehab, Inc.'s general counsel is Neil Hosenball, a former general counsel for NASA.

In the nascent field of space commerce, it pays to have connections. After his promising start, no-namer Citron, commuting from Seattle with a great business idea and customers in hand, ended up moving through the NASA bureaucracy like molasses. The all-stars later recruited to aid the Spacehab effort, promoting basically the same idea from a Washington, D.C. base, soon caught the notice of old NASA friends across the street. In March 1990, when the agency announced it was soliciting proposals for mid-deck expansion designs, it felt compelled to inform potential Spacehab competitors: "NASA is not aware of any other firm with the business maturity and possessing a design with the degree of technical maturity necessary to meet flight requirements." No challengers stepped forward.

After Lee had enlightened him on NASA's real needs, Citron contacted the Center for Space Policy, a Boston consulting firm that agreed to help guide him through the labyrinth of NASA contracting procedures in exchange for a piece of the company. Space Travel eventually became Spacehab Inc., an eight-person Seattle-based operation. Sometimes Citron was able to pay his staff; sometimes they had to accept shares of the company or a pep talk in lieu of a paycheck.

In need of marketing data to show potential investors, Citron took to the conference and meeting circuit, compiling a list of experiments waiting to fly and touting the virtues of flying them in Spacehab's lockers. Between 1984 and 1987 the company participated in dozens of conferences worldwide, eventually amassing a database from 14 countries that Citron says was "better than NASA's."

After managing to beat an MOU (Memorandum of Understanding, the first formal step toward an actual contract) out of NASA in late 1985, Citron brazenly began taking reservations for Spacehab flights whenever he attended a conference. "I had order blanks printed," he recalls, "and in just a couple weeks we had \$50 to \$60 million worth of orders for the first 10 flights, projected to start in 1989. Of course, these were noncommittal orders. But they demonstrated that the market was there."

The market was there in part because, during the Reagan administration, space had officially become the final frontier of capitalism. In 1984, presidential and congressional directives to promote the commercial use of space prompted NASA to create an office of commercial programs and try to whip up interest in space-based research. Two efforts have been particularly successful: Joint Endeavor Agreements (JEAs), in which NASA agrees to fly at no charge experiments developed and funded by private industry, and the Centers for the Commercial Development of Space (CCDSs), 16 consortia of academic and industrial partners started throughout the country with government seed money. Each CCDS focuses on a research area with potential commercial applications—crystal growth, materials development, robotics, pharmaceuticals—and generates experiments for NASA to fly.

That's a lot of experiments jockeying for space, but remember that in the mid-1980s, the shuttle was expected to fly almost weekly. And in addition to the eight lockers available for experiments on the shuttle's mid-deck, there was Spacelab, the European-built laboratory module that would be carrying experiments in the cargo bay on some flights.

Then in 1986 the *Challenger* exploded. "It stopped everybody, including me," says James Rose, assistant administrator for commercial programs at NASA, who at the time was at McDonnell Douglas overseeing a JEA experiment in biotechnology. The subsequent decelerated shuttle schedule seriously crippled industrial space experimentation; to make matters worse, Spacelab proved unsuitable for commercial

needs. The complexity of its systems makes integrating experiments a long process; at the moment, there is a minimum wait of four years to get on it. Moreover, because of its size, it requires dedicated flights. As a result, Spacelab has flown just four times in seven years. "If you're trying to develop a technology for industrial applications, one flight every year or two doesn't do you one bit of good," says Rose.

The *Challenger* explosion presented a rare marketing opportunity for the shuttle-expanding Spacehab. But it also made it next to impossible for Citron to find investment money for space projects. In 1986 he began looking for professional management to take the reins of Spacehab. The timing, he maintains, was coincidental. "I knew from the very beginning that I wasn't going to be able to take Spacehab full circle," he says. "A good entrepreneur knows his limitations, and I knew that at some point I would have to pass the baton on to high-powered professionals who could make this thing work."

As it happened, he passed the baton into the capable hands of McDonnell Douglas executive Richard Jacobson, a former Air Force colonel with a career in aerospace reaching back to the late 1940s. Jacobson was 66 and on the verge of retirement when Citron went headhunting—a circumstance that dovetailed nicely with the interests of Jacobson's boss, former NASA associate administrator John Yardley.

"Yardley thought it was a hell of an idea and a natural for McDonnell Douglas to get involved with because the company already had a division doing the integration work on Spacelab," Jacobson says. "But he didn't approve of Spacehab's management. So he said he'd do some cost-sharing with Citron and take the prime contractor role, but only if I took the company."

A congenial man with a military "can do" attitude, Jacobson considered the offer, talked to Lee and other friends in the business, and decided to join up. Citron, who chose to stay in Seattle, was eventually relegated to a seat on the board. He presently owns about two percent of the company.

After taking over in February 1987, one of the first things Jacobson did was relocate Spacehab literally across the street from NASA. "That was critical," he says. "You can't do something like this from Seattle. They had been negotiating an SSDA [Space Systems Development Agreement, which specifies the terms for flying a payload] with NASA for a year and were no closer to getting it than when they started." Jacobson estimates that for the next year and a half,

Spacehab president Richard Jacobson (left) assembled a NASA-savvy staff, including former agency administrator James Beggs.

CAROLINE SHEEN

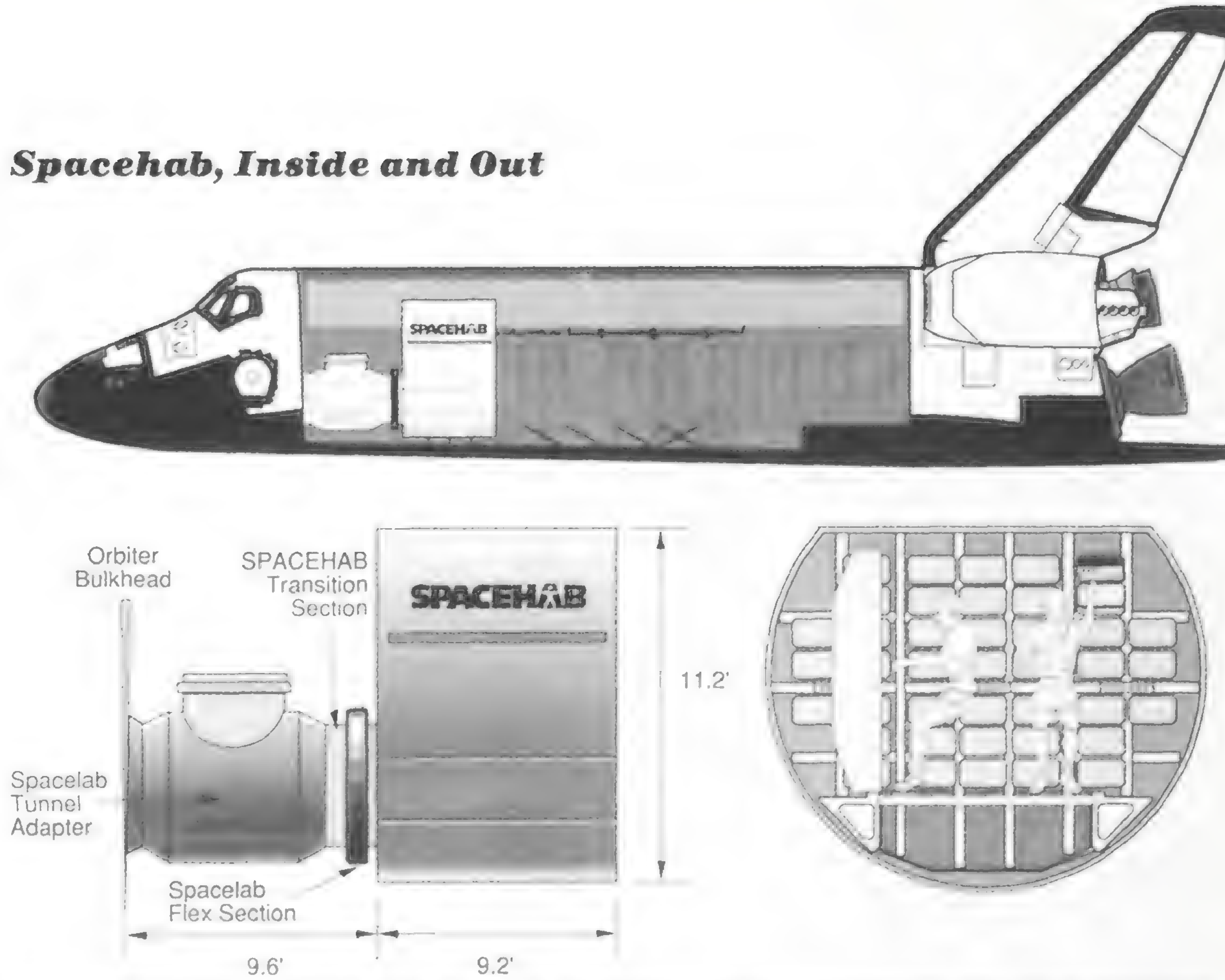
he was in and out of NASA offices three or four times a day nearly every day, hammering out terms that would satisfy both his investors and the space agency.

Jacobson began to assemble his staff of NASA veterans. His bagging of James Beggs was particularly impressive. Beggs, who had recently been cleared of charges of fraud stemming from his tenure at General Dynamics, had served as the administrator of NASA from 1981 to 1985. But soon a more pressing task appeared: Jacobson had been on the job only a few months when he discovered that the company was so broke it couldn't even afford to pay him.

He got on a plane to New York and started making the rounds of investment capital firms. The first year he brought in $2 million; eventually the company rounded up another $8 million from private investors, $12 million in loans and deferred billing from McDonnell Douglas and subcontractor Aeritalia, $9.5 million from a consortium in Taiwan, and $10 million from a Japanese consortium headed by Mitsubishi Corporation, where Jacobson had made friends while overseeing U.S.-Japanese aerospace projects at McDonnell Douglas. "We've known about the concept of Spacehab for quite a while," says Robert Carlson, the manager of Mitsubishi International's Huntsville, Alabama office, "but they did not have somebody who you could point to and say, 'Okay, this project will be done because this company is involved.' But when McDonnell Douglas became formally involved and Dick Jacobson became president, that immediately piqued our interest."

Until its customers have paid for their slots in full, Spacehab will still need a major bank loan to continue operating. Initially, Chemical Bank had agreed to provide $104 million, putting up a quarter of the money itself and getting the rest from three foreign banks, one in Japan and two in France. When Spacehab tried to renegotiate the commitment last year, however, the foreign banks got nervous about the whims of U.S. space funding and Chemical demanded 19 percent of the company. Jacobson decided to take his business elsewhere. Chase Manhattan is now committed to lending the company $75 million.

Spacehab, Inside and Out



Depending on locker configuration, Spacehab can transport two to three dozen experiments per flight.

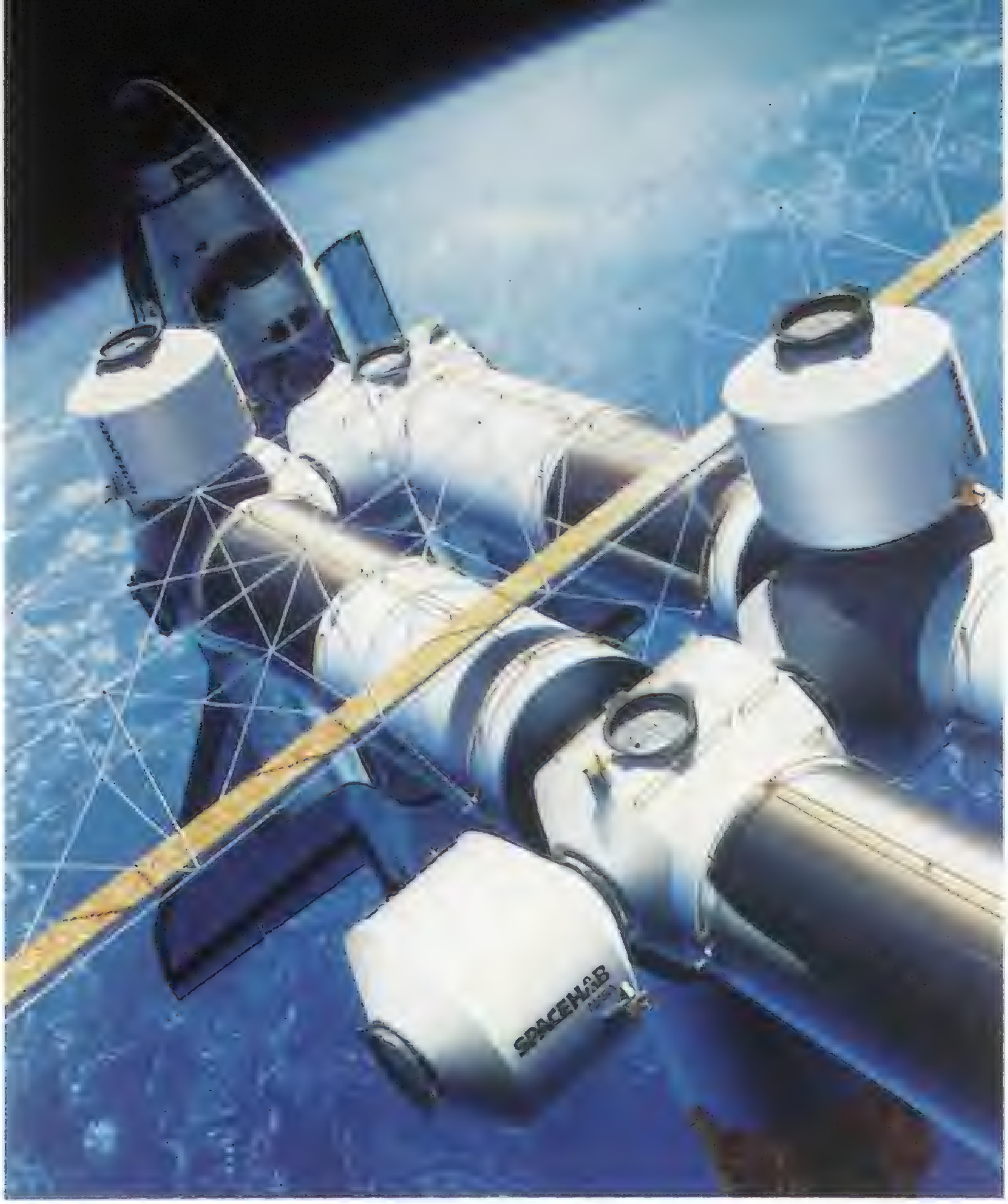
Jacobson had to run an equally byzantine maze to assemble Spacehab's first-of-a-kind insurance package, which was needed to secure financing. It took three years and a small army of brokers and underwriters to create an $80 million policy handled by Lloyd's of London. In addition to the normal insurance costs associated with spaceflight, Spacehab had to be insured against political risk—in case, say, Congress decided to cut funding for the shuttle program—which is something Lloyd's does not normally cover. But because both the Senate and the House included statements supporting Spacehab in their budget authorization recommendations, the firm's policy review board made an exception.

This sort of financial trailblazing is exactly what NASA's office of commercial programs hopes to stimulate, says James Rose. "You've got to have insurance brokers and bankers involved if you're going to truly have commercialized space," he explains. "We need companies like Spacehab to make those thrusts into the insurance community and the banking community and convince them that commercial space is going to happen, and we should all get out there and become part of it.

"NASA doesn't want to be in the business of selling or leasing a service to the Germans or Japanese or commercial companies in this country," Rose says. "It wants people like Spacehab to go out, borrow money from banks, develop this thing, and have markets other than NASA."

So why did NASA itself sign up as Spacehab's biggest customer, agreeing last November to pay $184 million to lease two-thirds of the locker space on the first six Spacehab flights? For one thing, the experiments the agency plans to fly on Spacehab are all products of the JEAs and CCDSs—experiments with commercial applications, developed in part by industry. And the leasing arrangement isn't as screwy as it seems: the terms of the SSDA contract stipulate that Spacehab pay upwards of $28 million per flight to ride on the shuttle, so nine-tenths of NASA's leasing costs are a wash. "A close analogy is the way the government helped create commercial air travel routes by contracting with various carriers to deliver the mail," says Lawrence Stern, senior research fellow at George Mason University's Center for the Study of Market Processes in Virginia. "Similarly, what it's doing here is trying to find a way to jump-start a commercial industry without actually subsidizing it."

The question of subsidizing commer-



A Spacehab marketing brochure offers this sleek dream: several modules docked with the space station.

cial space projects has aroused strong feeling in recent years. As Spacehab was wending its way through NASA, it encountered a potential competitor—a commercial mini-space station concept called the Industrial Space Facility (see "Space Stations in Lobbyland," December 1988/January 1989). During Congressional hearings on the ISF, Beggs used his NASA experience to great effect in promoting Spacehab and derogating its competitor. In a letter to then-congressman William Nelson of Florida, he complained that "conditions now being proposed for [the ISF] are significantly different" from those he had agreed to in 1985 as NASA administrator. Specifically, what Beggs objected to was the fact that the ISF required the federal government to sign on as its principal, or anchor, tenant. Spacehab, on the other hand, "*seeks no government funding or guarantees for use,*" Beggs wrote (his emphasis).

"That's pretty powerful, even though we knew it was a bunch of crap," says James Calaway of Space Industries, the Houston-based company that developed the ISF. "We kind of felt unfairly treated"—especially when Spacehab ended up asking the U.S. government to serve as its own anchor tenant. "Two years later, sure enough, there they were, hat in hand, asking for the same thing," Calaway says, speculating: "They never would have got financing otherwise."

But in addition to persuasive lobbying, Spacehab had another advantage over the ISF: it nicely complemented NASA's determination to continue the shuttle program, which had come under fire in the post-*Challenger* years. The ISF, on the other hand, was competing with a NASA program, and a huge one at that—the space station.

Even with financing and anchor tenant in hand, it's a little early for the staff of Spacehab to start popping champagne. As of January, Spacehab had leased only a third of its non-NASA-leased space for its first six flights. And just days after NASA had signed its leasing contract, a White House panel of aerospace experts recommended that the shuttle program be downgraded. Finally, part of the moral of the Spacehab story is that political connections count—and will continue to count.

The irony of the lesson is that despite NASA's party line about the need for commercial space enterprises to start thrusting their way into the jungles of private finance, Spacehab itself, making its ponderous way toward commercial viability, would probably never have gotten as far as it has without those knowledgeable NASA veterans willing to pitch in and help thrust it through NASA's bureaucracy.

That raises an old question of ethics: When contractors recruit former government officials, don't they acquire a competitive advantage in bidding on government contracts? Rose says no: "In the aerospace business, you find lots of small companies—'Beltway bandits,' isn't that what they're called?—who have the same background. That's how they know what they're doing." In other words, if everyone has an advantage, no one does. One could also argue that such government-to-industry shifting may be exactly what it takes to raise the confidence of those tempted to enter the space commercialization movement but wary of NASA's commitment.

Rose maintains that timing is more important than politics anyway. "Look at the Industrial Space Facility," he says. "They have some very highly respected people who have been in and out of the space business for years, and there was a lot of political clout being pushed around to make NASA use that thing. But it just didn't get through Congress. The reason Spacehab is successful is because I need it. If it wasn't for the CCDSs and the way they've matured, there would be no need for it."

Politics is an indelicate subject at the offices of Spacehab Inc. When asked how Spacehab attracted so much goodwill that presidents Reagan and Bush both mentioned it favorably in announcements of policy initiatives, Jacobson ponders a long time. Finally he will only say, "The answer is: you do a lot of work, okay?"

NATIONAL GEOGRAPHIC SOCIETY

THE HEIGHT OF AMBITION

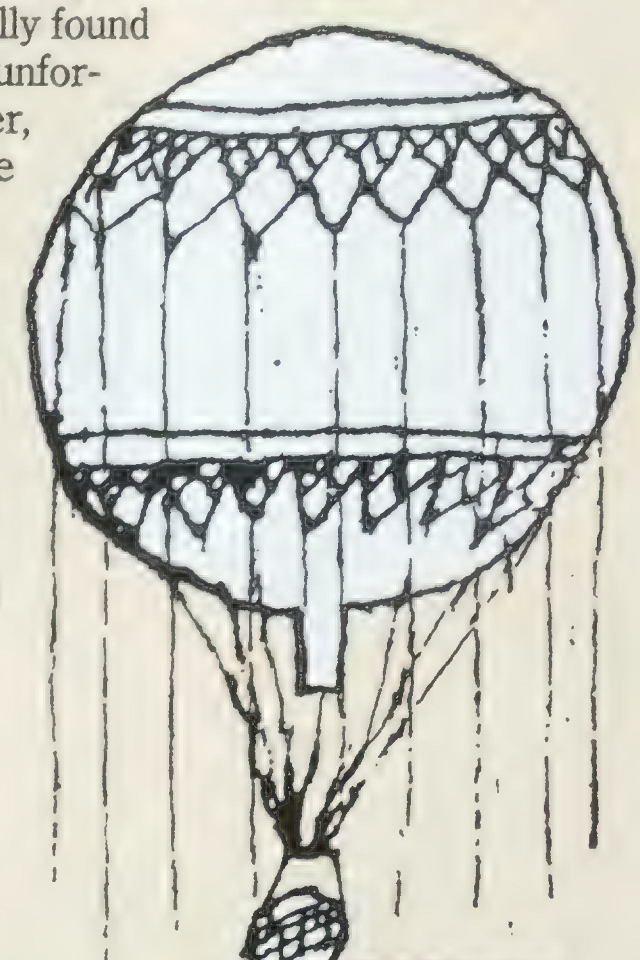
When pioneer balloonists penetrated the stratosphere in search of science, they found fame and fortune instead.

by David H. DeVorkin

Astronauts pass through it in a brief moment. Jet fighter and reconnaissance crews routinely prowl its middle and upper regions. And travelers on the supersonic Concorde experience the thrill of it for an hour or two, when they sense the nearness of space and witness the curvature of Earth. "It" is the stratosphere, the region of the atmosphere that begins some seven miles above the planet's surface and extends for 24. Here the weather is usually fair, but the air is perilously thin.

In the 1920s and '30s the stratosphere was a great unknown. It was the high frontier of human exploration, as the moon was in the 1960s and deep space is today. Airplane pilots who flew to nearly 40,000 feet and high-flying balloonists passed out from lack of oxygen, suffered frostbite, and generally found the high atmosphere a hostile and unforgiving place. Like any great frontier, the stratosphere attracted its share of adventurers who went seeking their fortunes but often met their deaths.

The stratosphere also drew the attention of scientists, who longed to solve the riddle of the elusive "cosmic ray," a catch phrase for a mysterious form of highly penetrating radiation whose source and nature were unknown. Solving ar-



LIBRARY OF CONGRESS

The flight of Explorer II *(left) marked the end of the heroic era of stratospheric exploration pioneered by Swiss physicist and balloonist Auguste Piccard. In 1929 Piccard sketched his balloon in a letter to his brother (right).*

Adapted and distilled from *Race to the Stratosphere: Manned Scientific Ballooning in America*, by David H. DeVorkin, Springer-Verlag, New York, 1989.

NASM

During his first flight, Hawthorne C. Gray (right) had the daunting task of releasing over 4,500 pounds of ballast.

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Two technicians pose with the gondola that enabled Auguste Piccard to survive two record-setting ascents.

CALIFORNIA INSTITUTE OF TECHNOLOGY ARCHIVES

Physicist Robert A. Millikan was never sold on the value of manned balloon flight for cosmic ray studies.

cane questions about the cosmic ray or the stratosphere's meteorology, however, couldn't fire public imagination and generate financial support. Headlines would be made by men who explored the stratosphere in balloons—men who could come back and tell the world in breathtaking detail what Earth looked like from ten miles up. For these explorers, science was little more than an excuse to make bigger and better flights.

Scientists who supported the use of unmanned balloons to make observations of the stratosphere grew to resent the advocates of human exploration, who, intent on setting new records, continued to package their flights as scientific endeavors. These conflicting interests never were resolved, presaging the discord that would arise decades later between advocates of manned space exploration and those who supported unmanned missions.

When it came to making headlines and piquing public interest in the 1920s, few succeeded as well as Hawthorne C. Gray. A captain in the Army Air Corps, Gray was an airship pilot who had dedicated himself to reaching the stratosphere. Unlike later organizers of manned ascensions, both he and Air Corps publicity officers heralded his mission for what it was: a daring reach to a new world's record. Accordingly, the instruments he carried along were designed for flight operations, not scientific study.

In March 1927, bundled inside nearly 60 pounds of clothing, Gray flew from Scott Field in Belleville, Illinois, to 28,500 feet, riding in an open basket and sustained by an oxygen mask. But like so many before him, he passed out at high altitude and suffered a crash landing, falling far short of the 35,424-foot record held by two Germans and the 40,820-foot mark that had recently been established by an airplane.

Gray tried again in May, reaching 42,240 feet, but when he bailed out at 8,000 feet to avoid another crash landing, he was disqualified for failing to land with his balloon.

Gray made his third attempt, again from Scott Field, on November 4, 1927. He managed to set a record of 42,470 feet, but this time his reach exceeded his grasp. When the balloon returned to 39,000 feet, Gray increased the speed of the descent, probably aware that his store of oxygen was dwindling. Ten minutes later the oxygen was gone. Gray probably fell unconscious soon after, forfeiting a chance to save his life by jumping to safety.

The next morning, a young boy found the balloon in the woods near Sparta, Tennessee. He climbed up the tree in which the wicker basket had become lodged and peered over the side. Gray's body lay curled in the bottom of the basket, his parachute still strapped on, his face concealed by the oxygen mask.

Gray's death proved one thing. New, safer techniques would be needed before others could hope to follow him into the stratosphere.

Auguste Piccard, a Swiss physicist, had his own agenda for exploring the new realm. A keen follower of the debate on cosmic rays, Piccard taught physics at the University of Brussels. He was also an experienced balloonist who had flown with the Swiss Army Observation Balloon Corps before and during World War I. He decided to make his mark in physics by combining his passions for flight and science: he would create a sealed, pressurized, manned laboratory that could be flown by balloon into the stratosphere to solve the mystery of the cosmic ray.

Starting in 1927, the 43-year-old Auguste wrote constantly about his plans to his identical twin brother Jean, a struggling inventor in the United States. They threw design ideas back and forth across the Atlantic, with Jean often hinting that the flight should take place on American soil, where "it would probably be easy to raise the money." Jean also wanted to fly. In one letter he offered his brother advice about publicity: "Too bad we can't make the trip together, as originally planned. You could most likely make a lot of money if you could commit yourself not to talk about the flight before you give a report to the Associated Press." Funding proved no problem, however. Auguste was a member of the new Fonds National de la Recherche Scientifique (FNRS), created by King Albert of Belgium. Such a flight would be a highly visible example of Belgium's revival in the fields of science and flight technology.

By the spring of 1929, Piccard had worked out his basic design for the balloon and gondola. The 500,000-cubic-foot, rubberized-cotton balloon was of the right size and strength to lift the 82-inch-diameter gondola, two crew members, 10

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Paul Kipfer retrieved instruments from the gondola, which soon attracted skiers who scratched in their names.

Coming from the ranks of the Army Air Corps, the crew of Explorer I *(above) nearly lost their lives in a midair explosion. The girdle that fastened the gondola to the ill-fated balloon was assembled at the Goodyear plant in Akron, Ohio (below).*

hours of life support, and instruments. Although the balloon was by far the largest expense, it did not pose the same technical challenge as the gondola, which had to be rigid enough to survive in the near-vacuum of the stratosphere yet electrically and magnetically neutral so that cosmic rays could travel unhindered through the sphere's skin. To keep the cabin air fresh and breathable, Piccard used a Draeger apparatus, a device he borrowed from World War I submarines that put out two quarts of oxygen every minute and removed harmful gases with an alkali filter. Auguste wrote Jean in March 1929 that he was worried about "the possibility of the blowout of the cabin. If I do have a metal cabin, it reduces considerably the perils . . . ." Piccard's concern was certainly well founded. A break in the cabin's seal would expose him to the stratosphere's dangerously low air pressure, and even if he had been able to breathe in such thin air, the sudden depressurization would cause decompression sickness, in which nitrogen bubbles begin forming in the blood and organs.

Among Piccard's advisors were engineers from the aluminum industry who had fabricated large vats for Belgian beer breweries. The engineers had just found a way to weld pure aluminum sheets into rounded containers that retained their integrity over great temperature ranges. For his exploration of the stratosphere, Piccard would fly in a sealed brewer's vat.

On the morning of May 27, 1931, Piccard and his assistant, Paul Kipfer, prepared to make an ascension from Augsburg, Bavaria. Motion picture cameramen filmed the scene and hundreds of spectators gathered around.

" . . . [T]here we were, bound for the stratosphere . . . . This was the moment I had spared no effort to live," Piccard later wrote in the *National Geographic.* Trouble began shortly after the 3:57 a.m. liftoff. Strong winds had knocked the gondola about while it was on the ground, creating a leak in the airtight cabin. As the balloon continued to rise, Piccard began a frantic effort to stop the leak. Eventually he succeeded with a mixture of oakum and Vaseline, while Kipfer set about straightening

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the instruments that had been scattered.

Within half an hour they had risen to almost 51,700 feet, nearly 10 miles up. The view was spectacular. In the *Geographic* account Piccard wrote, "The sky is beautiful up there—almost black. It is a bluish purple—a deep violet shade—ten times darker than on earth, but it still is not quite dark enough to see the stars. The sun, however, seems brighter .... Forests, rivers, and fields are visible ... with marvelous beauty in striking relief."

But more problems soon confronted the two aeronauts. When they tried to descend by valving gas from the balloon, they discovered that the rope mechanism linking their gondola controls to the exhaust valve was broken. In addition, they lost the ability to regulate the gondola's temperature. One side had been painted black to absorb sunlight and the other side left shiny to reflect it, but unfortunately, the mechanism for turning the gondola didn't work, leaving the black side facing the sun. The temperature inside the cabin soared past 100 degrees. "What heat! What thirst! What uncertainty!" wrote Piccard. With their supply of drinking water exhausted, he and Kipfer were in a fight for their lives. Just as their overtaxed respiratory systems began to fail, the arrival of nightfall began cooling the balloon's gas, enabling them to start descending rapidly. Luckily, they avoided the peaks and crevasses in the Austrian Alps and landed safely on a glacier in the Innsbruck region later that evening. The next morning, they walked down into a nearby village.

Little credence was placed in the one cosmic ray observation that Piccard had had time to make, but by then, scientists using other means had found the origin of the cosmic ray to be indeed cosmic. Piccard's observation drew only polite comments from Victor Hess, who first detected cosmic rays in 1912, and American physicist Robert A. Millikan.

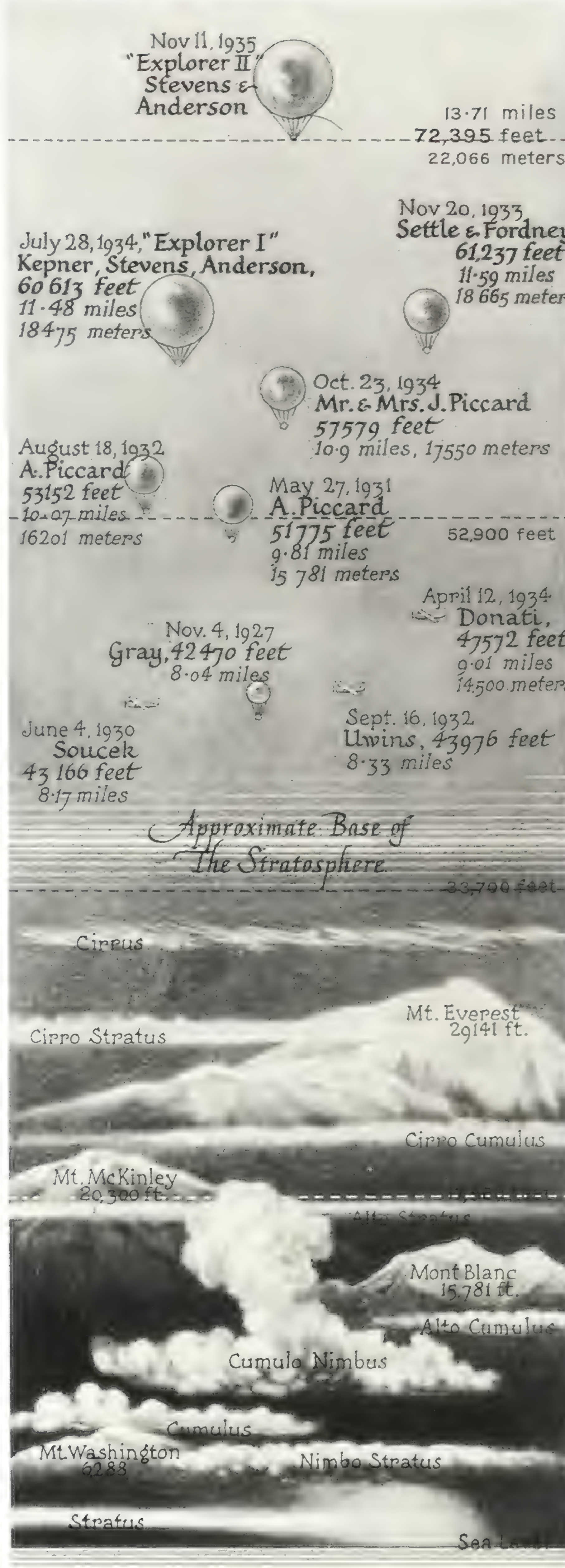
Scientists may have been lukewarm, but Piccard's altitude record of 51,775 feet made him a celebrity. Both Piccard and Kipfer were knighted, and a Belgian stamp was struck in their honor.

Thinking that the FNRS might not fund a second flight, Piccard told the *New York Times,* "I have no intention of going up again in a balloon. One experience such as that which befell Kipfer and myself this year is quite enough for a lifetime." But Piccard had a change of heart when funding for a second flight materialized. On August 18, 1932, he and physicist Max Cosyns ascended from Zurich to 53,152 feet, a new world record for manned balloon flight. This time almost everything worked according to plan.

The second flight yielded no new knowledge about cosmic radiation. Moreover, a few days earlier German physicist Erich Regener had sent automatic instruments to an unprecedented altitude of 16 miles. Regener's flight contributed far more than Piccard's to the picture of cosmic rays as a family of highly accelerated charged particles. Piccard continued to tout the value of manned flight for science, but by this time he was no longer a physicist. He was an explorer. Piccard's passion had become flight itself.

Piccard's successes came at just the right time to alleviate the pall Hawthorne Gray's death had cast over stratospheric ballooning in the United States. With great fanfare and

NATIONAL GEOGRAPHIC SOCIETY (2)



An international competition to capture the record for the highest manned ascent set off what one correspondent called "a race for supremacy in the stratosphere" (left). During its flight, Explorer II *viewed South Dakota from a height of nearly 14 miles in a photo-reconnaissance test (above).*

often wild rhetoric, Piccard captured the attention of the press and the public during a trip to the United States in January 1933. He gave stratospheric ballooning its scientific image, even though he remained on the periphery of cosmic ray physics. One reporter wrote: "If ever there was a typical 'professor,' it is Piccard! A man of medium height, he has the traditional flowing locks, the high wide, intellectual brow, the thoughtful eyes glinting behind spectacles and the courtesy one always associates with the academic."

In addition to wooing support for continued exploration, Piccard had a second reason for sailing to the United States: his brother Jean. As twins, the two Piccards were extremely close, but as scientists and entrepreneurs, they couldn't have been more different. Auguste was the careful, crafty one and Jean the impractical, impetuous dreamer. When Jean announced that he was about to get a job as a chemist with the Hercules Powder Company in Kenvil, New Jersey, Auguste pleaded with him to behave: "The most difficult task at the beginning will probably be dealing with people, to know how to treat each individual. Don't forget that everything unfavorable one says about someone is usually passed on to that person." Despite Auguste's advice, Jean feuded constantly with management and was eventually fired. Like hundreds of other scientists who lost their jobs during the Depression, Jean was unable to find employment, even with good references.

The fame that accompanied Auguste's successes in the stratosphere only increased Jean's despondency. More than anything else, Jean wished to repeat his brother's feat, hoping that success would lead to a tenured professorship somewhere. But the closest he could come was to accompany Auguste on his whirlwind American lecture tour, acting largely as factotum. Jean reported back to his wife Jeannette that he was being considered as a crew member on a new flight his brother was considering, one sponsored by the "A Century of Progress" world's fair in Chicago. "I could learn as well as [previous partner] Cosyns," Jean told Jeannette. When it turned out that Auguste had commitments in Europe and probably wouldn't be able to fly in the United States, Jean felt that he was the fair's next best bet. He was, after all, a Piccard.

Jean's ambitions to fly were more than matched by those of Jeannette. Her father, a prominent Chicago physician, could not understand his daughter's passion for this dangerous undertaking. But she was emphatic, writing him that she had many reasons to fly: "Some of them are so deep-seated emotionally as to be very difficult of expression. Possibly the simplest explanation is that we got started along the road and because I am I. I cannot stop until I have won."

With the possibility of a world fair's flight dangling before him, Jean traveled frequently to Chicago to negotiate with the flight's sponsors. To ensure good gate receipts for the launch, the planners wanted the flight to start from Chicago's Soldier Field. The parties also had to agree on what companies would manufacture and donate the balloon and gondola. And what would the flight be called? Who would gain title to the balloon and gondola after the flight?

NATIONAL GEOGRAPHIC SOCIETY/NASM (2)

The most problematic negotiation concerned the selection of the two-man crew. Perhaps it was Jean's intense desperation to achieve worldwide fame that alienated him from the exposition backers. Not trained as a pilot, Jean needed someone to man the balloon while he tended to the scientific instruments. However, one of the pilots under consideration, Ward T. Van Orman, already had misgivings. As he wrote in his book *The Wizard of the Winds:* "The day he [Jean] visited the Goodyear plant he bounced around all over the lot and insisted on drinking from the laboratory spigots instead of the drinking fountains in the hall . . . . When two are seated nearly in each other's laps for many hours ten miles above the earth, nothing is trifling."

As the negotiations dragged on, the flight's backers became anxious to rid themselves of Jean. They proposed sending Lieutenant Thomas "Tex" Settle, a Navy pilot of their own choosing, on a solo flight. The public rationale was that the lighter load would enable a higher altitude to be reached, thus increasing the chances of obtaining valuable scientific data. In reality, a solo flight for science was a nice cover for all parties concerned. It maximized the chance of grabbing the world's record while giving Jean an honorable way to back out.

After Explorer II *touched down (above), its two-man crew quickly ruptured the balloon to keep it from dragging the gondola (right).*

In 1946 Jean Piccard finally became a tenured professor, but he and Jeannette (opposite) never gave up their dream of returning to the stratosphere.

NASM

Settle lifted off on August 5, 1933, with an array of instruments supplied by physicist Millikan and his rival in the debate on the nature of cosmic rays, Arthur Holly Compton. A faulty valve forced Settle to abort after only 20 minutes. Before Jean could take possession of the balloon and gondola for a flight of his own, exposition backers declared that Settle deserved a second chance. On November 20, Settle and Major Chester Fordney pushed for and set a world's record of 61,237 feet, beating a record that a trio of Soviet balloonists had set three weeks earlier. Noting the marginal scientific return of Settle's two flights, neither Millikan (who would participate in three American ascents) nor Compton became a supporter of manned flight, preferring instead to pursue unmanned flights and ground-based studies. As for Jean, the entire experience greatly embittered him, but it also strengthened his resolve to reach the stratosphere.

He finally got his chance, leaving the ground from Dearborn, Michigan, on the morning of October 22, 1934, with Jeannette as his pilot. After the "Star Spangled Banner" had been played and the Piccard sons had given their mother a bouquet of flowers, Jean, his wife, and their pet turtle began the ascent in the refurbished balloon and gondola that Settle had used.

In a letter to a patron, Jeannette wrote: "When we make our flight . . . we will not attempt a new altitude record. We will try chiefly for scientific results and will try only to reach a height that will enable us to get such results. Altitude records have their place in the development of aviation. They are splendid achievements. To us, however, altitude is only a means to an end. The end itself is pure science, the search for Truth, from which practical science derives." Yet Jeannette had found time to design and market commemorative stamps and souvenir programs, as well as negotiate a lucrative news release agreement with the North American Newspaper Alliance that would give her and Jean a $1,000 bonus if they set a new altitude record.

The record they obtained, however, was not for altitude but for foolhardiness. They took off into a cloudbank and soon became lost. Even though they feared drifting over the Atlantic, they still tried for a world's record. They didn't come close. Furthermore, they lost the majority of their scientific data in a hasty crash landing.

Though scientists were becoming increasingly disillusioned with the likes of world fair promoters and explorers such as the Piccards, manned stratospheric exploration in the name of science didn't end with Jean and Jeannette. The era's final flight was that of *Explorer II.* Its two-man crew, Albert W. Stevens and Orvil Anderson of the Army Air Corps, set a record of over 72,000 feet on November 11, 1935. Supported by the National Geographic Society and the Army, *Explorer II* followed an earlier flight that had ended in the explosion of the hydrogen-filled balloon. To increase the margin of safety for *Explorer II,* a larger balloon was filled with helium, which has less lifting capability than hydrogen. Consequently, half of the scientific equipment was dumped, a frustrating blow to the many scientists who had devoted months to producing the instruments. Crew safety and a new altitude record had become the Geographic's main priorities.

Although the 1930s era of manned exploration of the stratosphere via balloons had ended, the idea of using science as the rationale for exploration spectacles did not. Thirty years later, the manned-versus-unmanned conflict resurfaced during the Apollo program, with Apollo's image the product of a carefully orchestrated media event encouraged by Cold War political pressures. Just as promoters in the 1930s connected record-setting with science, NASA sold exploration in the name of science, hoping to give Apollo a higher purpose than mere competition with the Soviet Union. What could have been a series of developmental ventures leading to a real mastery of a new realm became instead, in both eras, expensive stunts designed to make single, impressive statements. Indeed, Stevens of *Explorer II* wanted to continue flying, but his Army and Geographic patrons had met their own goals. To make the point, the society cut up the still-useful balloon into a million bookmarks for its members.

It is no surprise that neither manned ballooning nor manned spaceflight was readily embraced by the majority of the scientific community. Manned craft did not fulfill a need but created one: they needed scientific patronage to justify their creators' efforts. Even though Auguste had originally argued that one could trust a laboratory instrument controlled directly by a human observer, the majority of the instruments flown in the United States were automatic so that pilots would be free to handle the balloon.

And yet it would be wrong to say that nothing of value came from manned flights to the stratosphere. The technology that Auguste developed opened the door to human survival in this new realm. And as many people saw in the 1930s, there was something exciting about exploration for its own sake. As adamant as Jean and his wife were that their flights would be for science, to one reporter it was obvious that "to Adventurer Piccard, no gondola probing the unexplored purple twilight of the stratosphere would be complete without him and his wife in it."

Night Lights

In 1987 Michael Parfit flew 25,000 miles retracing Charles Lindbergh's 1927 goodwill tour around the United States. On board Parfit's single-engine Cessna Cardinal was a motorcycle, sleeping bag, laptop computer, tape recorder, and pads and pencils. Parfit noted all he encountered on his four-month journey, from weather to landscapes to people, in his book Chasing the Glory: Travels Across America. *He has combined material from several chapters in the following excerpt.*

Night, to the pilot, distills the landscape into simple light and darkness. When you drive in the dark, the highway blinds you. But in the sky no headlights shine; I open to the darkness. The airplane is a dim red-lit room where instruments tell their stories. Outside, the earth is primitive and strange. Human life passes beneath in swirls of glitter, as remote as galaxies, and in the light of moon and stars the land itself is silver shadows and blackness. I have seen night as dark as it once was, and as bright as we can make it. It is always beautiful; it is always strange.

Only in a few areas of the western United States can you fly on a clear night and not be surrounded by electric light. The vast wilderness between Boise, Idaho, and Missoula, Montana, is one such preserve. I have many times cast away the friendly illumination of the Snake River Valley and ridden north out into that darkness, knowing of the unforgiving teeth of the land below and seeing—or hearing about—odd lights.

Once, waiting anxiously for the moon to rise and give me at least a chance of making a forced landing if the engine quit, I searched in vain for a glow that would tell of its arrival, then looked away for what seemed like only seconds. When I looked up the whole moon was right *there,* sudden as an explosion, close as the spotlight of the law. Another night the wilderness was smothered in a haze of smoke, with a few stars shining faintly red above. A crescent line of fire crackled through the invisible woods. It looked like a tear in the fabric of the earth, revealing hell.

One night, when I was westbound for McCall, Idaho, over this empty landscape, the odd lights turned up in someone else's airspace. I crossed Salmon shortly after sunset and watched the glow of the small town drift slowly back and disappear behind the black shoulder of a mountain. I checked the navigation lights and listened more critically to the engine. As the sky darkened, a half-moon began to illuminate the earth, but it could not penetrate the wilderness. Occasionally, I watched the slow passage of a bluff of stone as it slid past beneath me like a breaching whale—barnacled, tarnished, and old. Once the mass below was briefly seamed by a river, which, reflecting the moon for a second, shone, then vanished. A mountain lake in a forest blinked a last glance at the fading sky, then slept, leaving the image of a pale eye and black lashes.

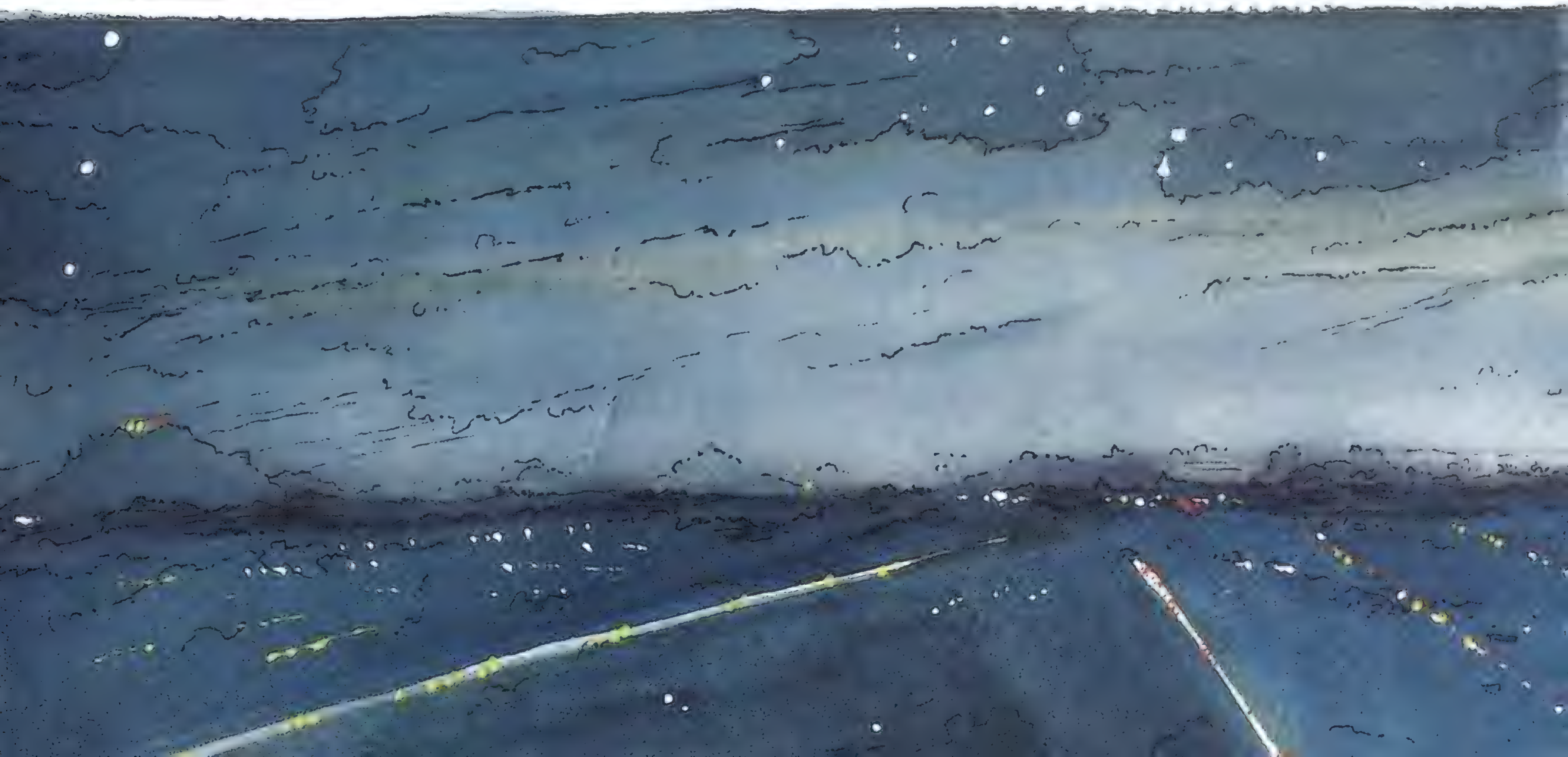
The only company was the radio. Other pilots, seldom identified by location, exchanged pleasantries with Salt Lake City air traffic control:

"Five Nine Yankee, level at eleven."

"Eight Eight Four Two Uniform, descend and maintain two five thousand."

"Roger, Four Two U."

BONO MITCHELL



Muffled by earplugs, the sound of my engine rumbled its steady comfort under this aerial routine: the mail chugging west, an airliner headed for Chicago, a tired writer going home.

Then, an interruption:

"Salt Lake, this is Seven Eight Mike."

"Roger, Seven Eight Mike, go ahead."

The voice was laconic:

"Ah, Salt Lake, do you have any traffic in our area?"

"Seven Eight Mike, negative traffic," Center said.

The voice was somewhere between Boise and Elko, flying through a void almost as dark as mine. There was silence for several seconds. Then 78M came back on the air, almost conversational, but with an undercurrent of tension.

"Maybe I'd better explain," he said. "The reason I asked about traffic was that we saw something out here."

"Roger," Center said, noncommittal. There was another pause. How many other pilots flying in this night were listening? The airliner, the mail plane, maybe fifteen others: a widespread collection of small rooms populated by men and women absorbed in watching instruments hum their tale of distance vanquished, now momentarily drawn to another story.

"We saw something that looked like it had its landing lights on. It also had a red light that was not blinking. It was about two thousand feet below us. The aircraft, if it was an aircraft, then turned and went away from us at a very high rate of speed."

The night was silent again. Center said, "Roger."

Seven Eight Mike spoke again: "When I say a very high rate of speed, I mean an extremely high rate of speed. The aircraft, if it was an aircraft, traversed a very great distance in very short order."

Center said something soothing about making a report and gave 78M a number to call in Oregon when he landed. But 78M, perhaps defending himself before the silent audience of other pilots on the frequency, added: "There were two other persons in this aircraft who saw the same thing."

That was all. Routine folded in again. The airliner going to Chicago climbed to heights unimaginable to me, the mail plane landed in Boise, and very slowly I flew west. The pale green lights of farms appeared over the black edge of the wilderness like an approaching army.

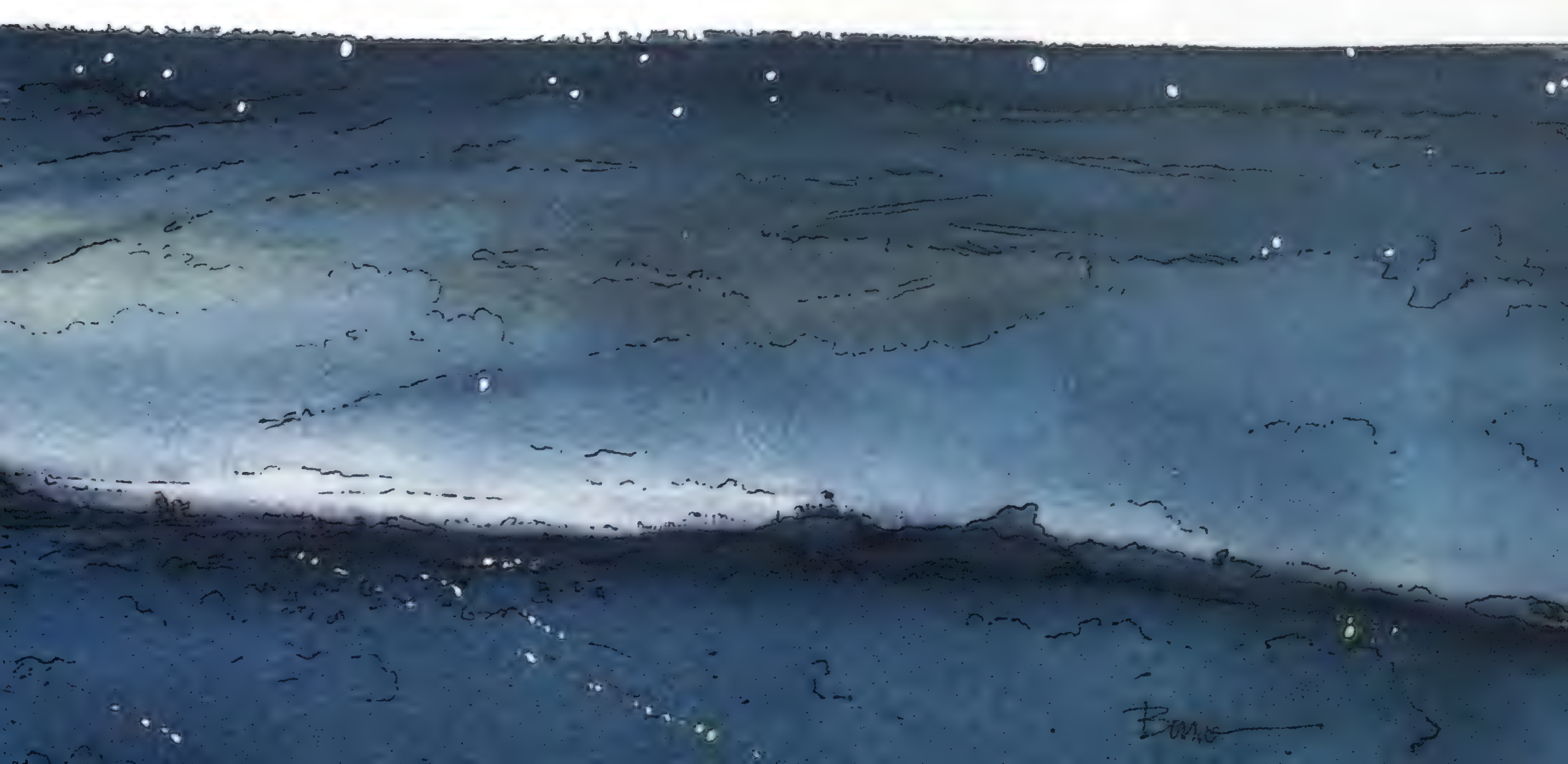
Humans dominate the night landscapes where they live. But in the dark the landscapes change their images. A town that seems in daylight to be a nondescript sprawl becomes a grid of baubles. Two commercial streets form a crucifix of neon fast-food signs and parking lots. Greenhouses stand out among farms like bars of platinum. Busy roads link villages into spangled chains. Parks and baseball stadiums, with their crescents of floodlights, are tiaras, shining crowns scattered among the subdued amber streetlights of the suburbs.

Once I took off from Fort Worth late at night, and as I rose the earth seemed tiled with light. The whole floor of my world was polished to a glow and grouted with incandescence. The few gaps in the expanse of illumination—a reservoir, a gravel pit—looked unnatural, like chunks dropped out of the world.

The expanse of light was multitudinous: the many crowns of the stadiums, the flood of red and white lights of heavy traffic, the packed lights of the multiple downtowns. Searchlights sliced through haze, dueling like light sabers. This was the gift of dams and power stations, of all those strands of wire that loop their way across deserts and mountains like threads of steel binding the land. Coal burned, water fell, the city shone.

A vapor of moisture and light filled the world. The haze stood two thousand feet deep, bright and tangible, each drop of vapor a globe of reflected light. At my elevation I was just above the line of inversion that trapped the murk and the light that occupied it: the illuminated haze ended in a level line. Its surface was as distinct as the skin of water; I sailed on it as on a sea, floating on the tension and density of light itself. The light rolled along, reflected, on the bottom of my high wing. The world was upside down. I would have had to spill the buoyant dark out of my wings and tanks, and weigh myself down with 100-watt bulbs, all turned on, to be heavy enough to sink.

But I did not wish to descend. I reduced power, held altitude, and floated. I was happy here. For a while I lived on wishfulness: Do not bring me day. Do not make dust out of this glitter. Let me run my fingers through this treasure and drape diamonds on my shoulders, and pretend there is no morning.



Divine Inspiration

The appearance of the wheels and their work was like unto the colour of a beryl: and they four had one likeness: and their appearance and their work was as it were a wheel in the middle of a wheel.

And when the living creatures went, the wheels went by them: and when the living creatures were lifted up from the earth, the wheels were lifted up.

—Ezekiel 1:16, 19

"Are detailed instructions for the building of the modern airplane given by divine revelation through the Scriptures?" asked the *Dallas Morning News* in 1923. Burrell Cannon, a Baptist preacher born in 1848, believed the answer was yes. Like many inventors at the turn of the century, Cannon tried to build a flying machine. Unlike the others, he found his inspiration in the Holy Bible's book of Ezekiel.

Cannon had long been fascinated by Ezekiel's description of a four-wheeled flying machine inhabited by four winged creatures that descended from the heavens. According to Lacy L. Davis, a longtime resident of Pittsburg, Texas, who has researched Cannon's life, the minister's bible shows much wear on the pages of Ezekiel, particularly the first 10 chapters.

No one knows when Cannon, who was born in Coffeeville, Mississippi, arrived in Texas. "He was considered an educated man," says Davis. "He could speak several foreign languages and was trained as a blacksmith and machinist. He was an ordained Baptist minister and, by his death, a 33rd degree Mason and chaplain of his lodge." The twice-married Cannon supported his family by running a sawmill in Pine, Texas, but spent Sunday mornings preaching in a one-room schoolhouse.

Cannon studied Ezekiel's description of his vision for 16 years, eventually coming to believe that God had intended for man to fly. Like Noah building the ark, Cannon worked steadily from what he considered divine blueprints, building models of what would become the Ezekiel Airship.

By August 1901 Cannon was ready to take the next step toward actual flight. Convincing friends in nearby Pittsburg, a small agricultural town in Texas' Camp County, that his invention had the potential to fly, Cannon incorporated the Ezekiel Airship Manufacturing Company for $20,000 and started selling stock at $25 a share. He told a newspaper reporter that the specifications for Ezekiel's many-wheeled wonder "embraced the highest laws of mechanical genius and were the perfection of science."

Although Cannon truly believed that God wanted man to fly, it took more than faith to persuade investors to part with their money. The enterprising parson told stockholders that his airship could carry a payload and that they would become millionaires from sales to the postal service and the military. So successful was Cannon's pitch that the company's vice president, P.W. Thorsell, provided work space on the upper floor of a new red-brick building that was part of his Pittsburg Foundry and Machine Shop.

Construction began in March and was completed in October 1902. "It was not an airship as we know them, filled with air or gas," Davis explains. "Nor an airplane designed to be pulled or pushed by a propeller, nor a helicopter with a whirling blade to lift it up. It was different from any other aircraft before or since." According to a Camp County Chamber of Commerce brochure, the result was an aircraft "with large, fabric-covered wings powered by an engine that turned four sets of paddles mounted on wheels. By means of a lever the pilot could take off vertically and maneuver by controlling the angle of the paddles."

"It is amazing that such a heavy-looking airship did get off the ground," says Camp County Chamber of Commerce vice president Les Stratton Jr. But fly the Ezekiel Airship did, according to eyewitnesses.

PHOTOS COURTESY LACY L. DAVIS

The craft was piloted by one of two brothers who worked at the machine shop, Gus and J.B. Stamps. "No one remembers which one," says Davis. "But before his death he returned to visit Morris Thorsell [son of P.W. Thorsell] in 1922 or 1923 and talked about the first flight."

According to Stamps' account, the flight occurred sometime in the winter of 1902-1903. The airship was taken to a pasture near the Thorsell family home, where the designated Stamps brother got in and started the engine. The airship rose some 10 or 12 feet, then drifted toward a fence and began to vibrate, prompting Stamps to shut down the engine. Stamps blamed the vibration on the lack of an adequate chain-link drive for the engine. Because investors had become discouraged, Cannon's funds had dried up and he had had to make do with inferior parts.

Burrell Cannon got the inspiration for his airship design from the Bible.

Stamps also gave Thorsell the somewhat surprising news that he and the other workmen had secretly removed the airship from the machine shop and prepared for the first flight without informing Cannon or any of the company directors. For that reason, Davis believes the flight occurred on a Sunday morning. "The workmen would have had the day off," he says, "and the directors would have been off in church. I knew many of these men personally—every time the church doors were open, they'd be there."

It makes sense that Cannon would have been at the pulpit on Sunday morning, but Stamps' story is steadfastly contradicted by Cannon's granddaughter, Lenita Tacea, who lives in the New Orleans area. "She's told me that Reverend Cannon was there giving very explicit instructions to Mr. Stamps that Sunday," says Davis. "She added that the reverend wanted to fly himself, but being over six feet tall and weighing more than 200 pounds, he felt himself too large."

Unfortunately for Cannon, Pittsburg's businessmen did not consider Stamps' flight a great success. After failing to get more funds from his stockholders, Cannon decided to take his aircraft to St. Louis, Missouri, perhaps to exhibit it at the 1904 World's Fair or perhaps to seek other backers. The airship was loaded onto a railroad car, but a sudden windstorm blew it off the flatbed near Texarkana and it was completely destroyed. According to granddaughter Lenita, Cannon declared that "God never willed that this airship should fly. I want no more to do with it." And he walked away, leaving the pieces on the ground.

The aviation bug had bitten, however. From 1908 to 1913, Cannon sold stock in another airship company while living near Longview, Texas, according to Mrs. C.F. Gordon, his now-deceased stepdaughter. His second aircraft was built in Chicago, where it was flown in 1913 by a man named Wilder. This ship too met with disaster. As it lifted into the air, it hit a utility pole. Once again Cannon had to give up his dream.

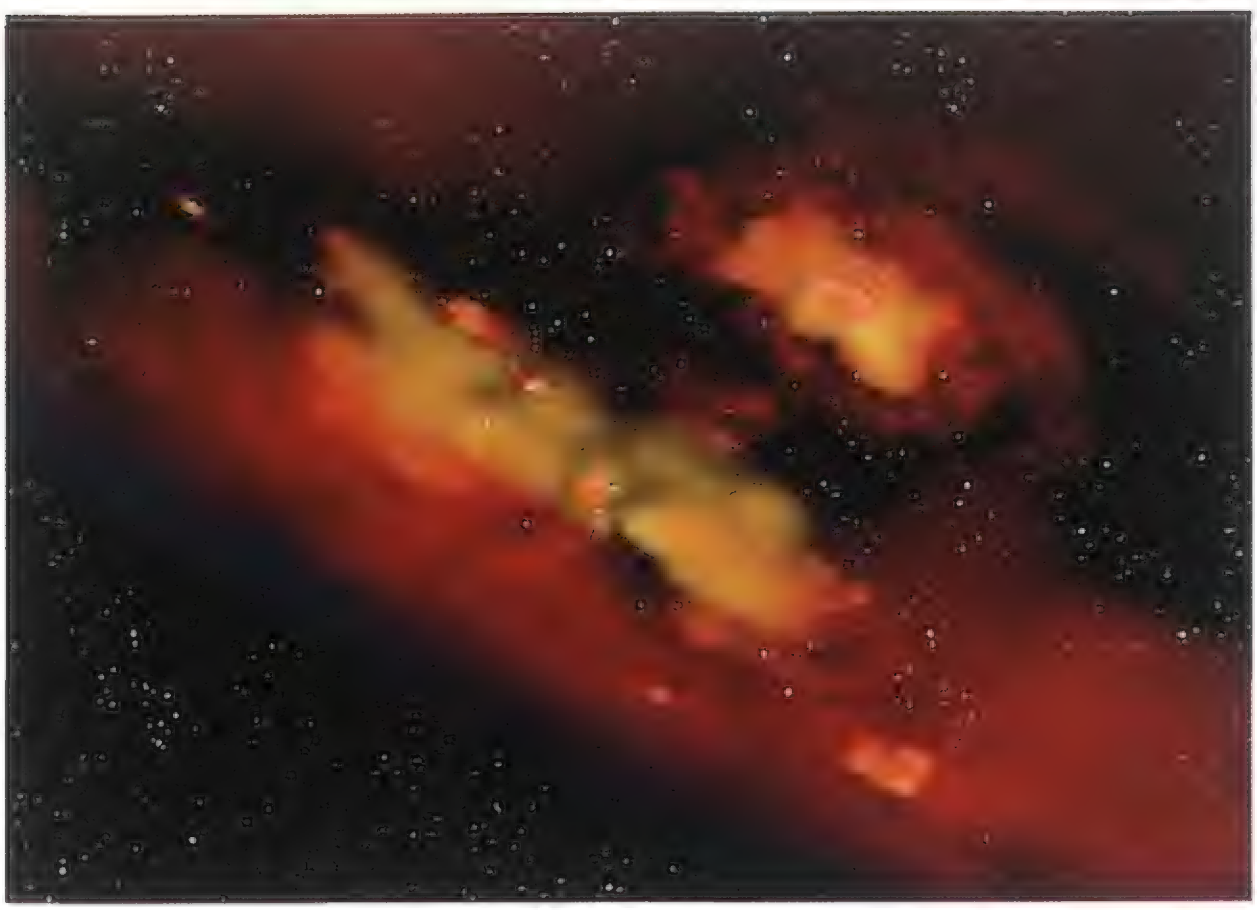
In 1922 the minister died in Marshall, Texas, at the age of 74. A ceaseless inventor, he had been working on a cotton picker and a boll weevil destroyer.

Over the years, the Thorsell machine shop changed ownership. It still stands on Fulton Street, though it has fallen into disrepair. Most of the people who witnessed the flight or had firsthand knowledge of the aircraft's construction are dead. "There's so much that we cannot pinpoint at this late date," says Davis.

In 1975 the Camp County Historical Committee decided to obtain a marker commemorating Cannon's Ezekiel Airship. But first the county had to prove the airship's existence to the Texas Historical Committee in Austin. While conducting his research, Davis discovered the most conclusive evidence yet: three rain-soaked cardboard boxes stored in the machine shop's upper workroom. Inside the boxes Davis found some 30 timesheets with an entry for "airship" filled out by machine shop employees.

Davis got the marker. It is posted in front of the pasture where Stamps and the Ezekiel Airship left the ground. And in September 1987 the Pittsburg Optimist Club completed a 23-foot-long, full-scale airship replica that sits in the dining room of Warrick's Restaurant in downtown Pittsburg. With such constant reminders, the people of Camp County will never forget the Reverend Burrell Cannon and his ill-fated flying machine.

—Richard Sassaman



KLEISER-WALCZAK

"The Astronomers," *a six-part series produced by KCET/Los Angeles. First episode premieres on PBS on April 15 at 8:00 p.m. EST.*

The Astronomers *by Donald Goldsmith. St. Martin's Press, 1991. 352 pp., color and b&w photos, $24.95 (hardbound).*

Near the summit of Mauna Kea on the big island of Hawaii, under night skies so dark and clear the stars seem close enough to touch, stands a rotund building housing the world's greatest optical telescope. When it is fully operational a year or so from now, the W. M. Keck Reflector will collect four times more light than the venerable Mt. Palomar 200-inch, transforming Mauna Kea from a center for astronomy into a veritable Mount Olympus. Astronomers from around the globe will journey to the Keck dome like pilgrims to a shrine, hoping to gather information about the farthest reaches of space and time. Humanity will have opened a new window on the universe.

It is a window very few will have the privilege of looking through, for all the professional astronomers on our planet—about 6,000—could assemble comfortably inside Radio City Music Hall. And only a select number of *them* will get time on the big 'scope. The things they discover will gradually reach the public through popular magazines and books, but most of their work will be published first in technical journals read only by a handful of specialists.

For astronomy, and for science in general, this is not a good state of affairs. Ideally, science should inform its public as well as its practitioners. That is why it is so encouraging that the Keck Foundation, which has funded the telescope, has also funded—with a hefty $5.3 million grant—a popular exposition of what such an instrument will do. Lavishly produced and artfully edited, the PBS series "The Astronomers," along with a companion book by the same title, lets us look through the eyes of the men and women who make their living using the big telescopes and asking the big questions.

Research in astronomy is mostly tedium: long hours of fighting sleep amid the hum of electronics, months of analysis, occasional conferences where progress is reported and results debated. Yet there are moments of pure excitement—when a single observation confirms a hunch, when an unexpected result suggests new understanding, when the astronomer sees something no one before has ever seen. There is also the delight of watching the moon rise over a sea of clouds, or of sharing the heights with a circling hawk.

Like the view through a telescope, these are private things, hard to convey on the television screen. But "The Astronomers" brings them across by combining portraits of scientists at work, stunning shots of local scenery, and some dramatic computer-generated images. (The image at left shows our sun coalescing out of interstellar gas and dust, with proto-planets forming around it.)

Each of the series' six episodes centers on a small group of individuals and their research. In the first segment—"Where is the Rest of the Universe?"—the Carnegie Institution's Vera Rubin searches for the invisible "dark matter" that may make up 90 percent of the universe at large, and Bell labs' Tony Tyson describes his search for this matter in the most distant objects in the universe. At one point, while the voice of amateur astronomer John Dobson (a former Vedantic monk) drones an ancient Buddhist chant, the summit of Mauna Kea appears, surrounded by wisps of fog. It's a vision of dramatic beauty.

In the remaining episodes, we travel to Japan, Moscow, New Mexico, and Australia for investigations into the lives and deaths of stars, the birth of solar systems, the properties of black holes, and the earliest seconds of the Big Bang.

Everyone interviewed, of course, is an astronomy enthusiast, and sometimes it gets a bit tiresome hearing repeated expressions of awe and wonder at the mystery and unity of it all. But isn't it remarkable that those who work in astronomy night in and night out retain

such a passion for it?

If it all seems to go by a bit fast at times, Donald Goldsmith's breezy companion book proves a handy playbill, as well as a readable introduction to modern astronomy. The book contains lots of colorful illustrations and vivid background material on the research and the personalities portrayed in the series. Take the book to bed with you after each episode. Better yet, go out and gaze at the sky for a few minutes. Thanks to projects like the Keck Telescope and the astronomers who participate, we'll all understand the heavens better in the years to come.

—Laurence A. Marschall, author of The Supernova Story, *is a contributing editor of* Air & Space/Smithsonian *and a columnist for* The Sciences. *He is a professor of physics at Gettysburg College.*

Benjamin O. Davis, Jr.: American *by Benjamin O. Davis, Jr. Smithsonian Institution Press, 1991. 442 pp., b&w photos, $19.95 (hardbound).*

Benjamin O. Davis, Jr., the Air Force's first black general, has written an autobiography as dignified, spare, and lean as the man himself.

Davis commanded the tenacious Tuskegee Airmen during World War II. His triumphs and those of his men undermined the basis for segregation in the Air Force by destroying the myth of racial inferiority.

The Tuskegee Airmen shot down more than 100 Luftwaffe aircraft, destroyed many German aircraft on enemy airfields, and pummeled road transportation all over Hitler's Europe. In 200 escort missions to some of the most heavily defended targets in Hitler's Axis, Davis' men never lost a friendly bomber to an enemy fighter. No other fighter group with as many missions could assert that claim (see "The Flight of the Bumblebee," October/November 1989).

Air Force pragmatists saw that blacks who were given the same training as whites performed as well, and the Air Force became the first large institution in America to desegregate. By the early 1950s all the military services integrated, not for reasons of morality but out of the fundamental need for military effectiveness. By the mid-1960s the rest of the United States followed, in part because the armed forces had demonstrated the success of integration a decade earlier. The first seeds were planted by Ben Davis.

That accomplishment could have been enough for one lifetime, but Davis achieved much more. His busy life is crowded into this volume: In measured, dispassionate language he tells of the painful years when he was "silenced" by his fellow cadets at West Point in an effort to freeze him out, the repeated humiliations he and his wife Agatha had to endure in the racist military of the 1930s and '40s, the victories of World War II, and the numerous and critical post-World War II assignments. After retiring from the military as a three-star general, Davis served as Cleveland's director of public safety and the U.S. Department of Transportation's assistant secretary for safety and consumer affairs. Under his tenure there in the early 1970s, domestic hijackings were wiped out.

Benjamin O. Davis, Jr.: American is an important book, and the author has performed yet another public service in writing it.

—Alan L. Gropman is a military historian and author of The Air Force Integrates: 1945–1964 *and* Benjamin O. Davis, Jr.: History on Two Fronts.

The Cambridge Encyclopedia of Space, *edited by Michael Rycroft. Cambridge University Press, 1991. 385 pp., b&w and color photos, diagrams, and maps, $65 (hardbound).*

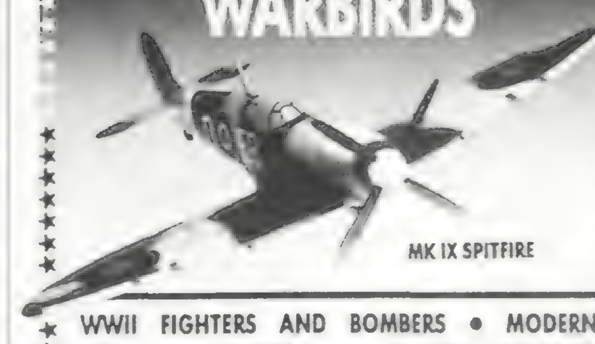
Cambridge University Press has combined the best of two worlds to produce this impressive volume: the large format and

lavish illustrations of a coffee table book and the depth and scholarship of a serious reference work.The book methodically takes its readers from the dreams of early visionaries through the hard realities of international space law, thoroughly covering every major step of manned and unmanned space exploration along the way. One of the book's strengths is the cutaway views of virtually all the spacecraft it discusses, such as the Gemini capsule, the Ariane IV launcher, and the space shuttle.

Perhaps predictably, the encyclopedia's weakest portions are its discussions of future space activities, which suffer from a promotional tone that sets them apart from the clear-eyed historical perspective of the rest of the book. Even these sections, however, have the sheer comprehensiveness that makes *The Cambridge Encyclopedia of Space* a valuable and enjoyable resource.

Singing the Vietnam Blues: Songs of the Air Force in Southeast Asia *by Joseph F. Tuso. Texas A&M University Press, 1990. 268 pp., $14.95 (paperback).*

Between May 1968 and April 1969, Major Joseph F. Tuso flew 169 combat missions in Southeast Asia, 77 of them over North Vietnam. "My two main interests," he recalls, "were combat flying and letters to and from my family." But Tuso had two other interests that filled the idle hours between rides in the backseats of various F-4D Phantoms and "helped make being at war more bearable." He taught English classes for a night extension program, and



he collected the home-grown songs that were being sung in "O clubs" and bars at U.S. Air Force bases across Southeast Asia.

Singing has been a part of military life since the time of Julius Caesar's legions. Soldiers sing to count cadence, to remind themselves of home, to celebrate the exploits of their fellow warriors, to strengthen their own bonds, and to express their opinions on issues ranging from the quality of their weapons to the wisdom of their superiors. Since the first airmen flew into combat, the members of the world's air forces have done their level best to uphold the age-old tradition of military song.

As the author notes, songs were a major part of the social life at sprawling bases like Phu Cat, Cam Ranh Bay, Korat, Ubon, and Udorn. "We lived a life very similar to that of the *comitatu,* or band of Anglo-Saxon warriors in the Old English heroic poem *Beowulf,*" he explains. "The center of our social life was our great hall, or Officer's Club." Here the members of this exclusive band of modern warriors gathered to feast and drink, to initiate new arrivals into the group, to bid farewell to departing comrades, and to toast their lords—the squadron and group commanders at the head table.

The songs they sang on such occasions

were usually the product of local minstrels, with tunes often based on well-known popular songs. But the lyrics were nothing if not original.

Some songs told of heroes. During the

VINCENT DI FATE

GEORGII POPLAVSKI

In the Stream of Stars: The Soviet/American Space Art Book, *edited by William K. Hartmann, Andrei Sokolov, Ron Miller, and Vitaly Myagkov. Workman Publishing, 1991. 183 pp., color illustrations, $19.95 (paperback); $29.95 (hardbound).*

The artistic cooperation *In the Stream of Stars* celebrates is an outgrowth of the efforts of an international association of space artists (see "The Place-That-Looks-Like-Mars Mission," February/March 1989). In this beautiful book, the American artists' tendency toward scientific realism and the Soviets' more emotional symbolism merge satisfyingly, like two halves of a whole. Containing essays by luminaries in the field and a galaxy of superbly reproduced paintings, *In the Stream of Stars* offers vivid evidence of our bold dreams for space exploration.

fighting in the A Shau Valley on March 10, 1966, Major Bernard M. Fisher, call sign "Hobo 51," landed his single-seat, propeller-driven A-1E in the face of heavy ground fire to rescue a downed comrade. The incident earned Fisher one of the 12 Congressional Medals of Honor awarded to U.S. Air Force personnel during the Vietnam War, and it was celebrated in a song sung to the tune of "The Wabash Cannonball":

Listen, A Shau Tower, this is Hobo Fifty-One;
I want to use your runway although it is overrun;
A friend of mine is down there a-hiding in a ditch;
I want to make a passenger stop and save that son-of-a-bitch!

The aircrews sang about their own bases and about the places they visited. Some songs expressed the jaundiced affection of the airman for his machine, and others were about specialized aircraft and missions. There were even vocal tributes to the MiG-19 and MiG-21.

If this collection is any gauge, the F-105 inspired more songs than any other aircraft in the conflict. Here we are treated to "Thud Drivers in the Sky," "Thud Pilot," "F-105 Alma Mater," and "The Thud Driver's Dream," among many others. "Republic's Ultra-Hog" is typical of the lot (the tune, again, is "The Wabash Cannonball"):

Listen to the jingle, the gruntin' and the wheeze,
As she rolls along the runway by the BAK-9 and the trees;
Hear the mighty roarin' engine as you leap off in the fog.
You're flying through the jungle in Republic's Ultra-Hog.

The airmen of this generation inherited some of their songs from their fathers and older brothers. "The Ballad of Machete Two" had been sung by P-51 pilots a quarter of a century before F-4D crews at Ubon, Thailand, came up with a slightly different version (to the tune, once more, of "The Wabash Cannonball"):

Hello, Ubon Tower, this here's Machete Two,
It's rainin' on the runway, O Lord, what will I do?
My gas tank's gettin' empty, and I am puckered tight.
Tell me, Ubon Tower, why must we fly at night?

Though some of these songs express the universal fears and frustrations of all airmen, others deal with the peculiar horrors of the war in Southeast Asia. No other war had ever generated a song quite like "Chocolate-covered Napalm" (sung to "Get Along Home, Cindy, Cindy"):

Oh, chocolate-covered napalm is raining from the sky,
Chocolate-covered napalm is made for you and I;
It's so much fun to drop it, and here's the reason why,
When it finally hits the ground, it makes the people fry.

Jerry Livingston's 1955 hit tune, "Wake the Town and Tell the People," served as a vehicle for what was perhaps the best known parody of the war, "Strafe the Town":

Strafe the town and kill the people,
Drop your napalm in the square;
Do it early Sunday morning,
Catch them while they're still at prayer.

The lyrics of these songs can be seen as black humor carried to the point of obscenity. The author, however, interprets them as expressions of revulsion, horror, and despair—anti-war statements offered by the warriors themselves.

Tuso spent 15 years collecting and annotating the 148 songs that appear in this book. It was worth the effort. Other books will provide you with facts, figures, and opinions on the air war in Vietnam. This book gives you something much more difficult to find: insight into the hearts and minds of the aircrew who fought the war.

—Tom D. Crouch is chairman of the department of aeronautics at the National Air and Space Museum.

Calendar

April 3–6
Professional Aeromedical Transport Association Seminar. La Maison del Rio Hotel, San Antonio, TX, (800) 541-7517.

April 5–7
Ozark UFO Conference. Inn of the Ozarks, Eureka Springs, AR, (501) 354-2558.

April 6
Airlines International Convention. Buy, sell, and trade airline memorabilia. Holiday Inn, Dallas-Fort Worth North, Irving, TX, (817) 847-2106.

April 6 & 7
Texas Air Expo. Thunderbirds and Golden Knights. Texas State Technical Institute Airport, Waco, TX, (800) WACO-FUN.

April 17–19
Corporate Aviation Safety Seminar. Westchester Marriott Hotel, White Plains, NY, (703) 522-8300.

April 27 & 28
Kitefest. Kite-flying games and kite-making workshop. River Oaks Park, Kalamazoo, MI, (616) 383-8778.

May 3
30th Anniversary Celebration of America's First Manned Space Flight. Sponsored by the Mercury Seven Foundation. Guests include the Mercury astronauts, Bob Hope. Washington Hilton Hotel, Washington, DC, (202) 659-4805.

May 3–5
Ava Aero Days '91. Aviation swap & shop, pig roast, and dance. Bill Martin Memorial Airport, Ava, MO, (800) 338-5752.

May 5
Behind-the-Scenes Tour of the New England Air Museum. A look at restoration projects. Bradley International Airport, Windsor Locks, CT, (203) 623-3305.

May 7–9
International Society of Women Airline Pilots' 14th Annual Convention. This year's meeting will be in Helsinki, Finland. Write: P.O. Box 38644, Denver, CO 80238.

May 9 & 10
"Naval Aviation Response to World Crises." A symposium sponsored by the Naval Aviation Museum Foundation and the U.S. Naval Institute. Pensacola Civic Center, Pensacola, FL, (800) 327-5002.

May 10–12
19th Annual Hang Gliding Spectacular. Jockey's Ridge State Park, Nags Head, NC, (919) 441-4124.

May 15–18
Space Studies Institute Conference on Space Manufacturing. Topics include lunar bases and space biospheres. Princeton University, Princeton, NJ, (609) 921-0377.

May 18–June 23
"The View From Space: American Astronaut Photography, 1962-1972." Smithsonian Traveling Exhibition. U.S. Air Force Academy, Colorado Springs, CO, (719) 472-1818.

May 22–27
International Space Development Conference. Sponsored by the National Space Society. Hyatt Regency Hotel, San Antonio, TX, (512) 520-4821.

May 25–July 7
"Exploring the Planets." Smithsonian Traveling Exhibition. Dane G. Hansen Memorial Museum, Logan, KS, (913) 689-4846.

May 26
Confederate Air Force Airshow. Stephens County Airport, Breckenridge, TX, (817) 559-2301.

Credits

Learning Curve. Ron Dick is the International Fellow at the National Air and Space Museum.

Flightseeing Tour. Phil Scott, formerly managing editor of *Flying*, is now managing editor of *Omni*. He enjoys watching airliners land at La Guardia from his apartment in Queens.

Stall Tactics. Preston Lerner is a freelance writer based in Los Angeles. His book *Scarab* (just published by Motorbooks International) is about another blue and white high-performance machine: a Formula 1 race car.

"My Body Will Collapse Like a Falling Cherry Blossom." Hatsuho Naito managed wind tunnel tests on special weapons, including the *Ohka* suicide bomb, as a technical officer for the Japanese Imperial Navy's aeronautical research laboratory in the 1940s. His book *Thunder Gods: The Kamikaze Pilots Tell Their Story* (Kodansha International, 1989), from which this article is adapted, is the first of his several books on the Japanese military to be translated into English.

The Space Shuttle's Family Tree. Richard P. Hallion is the Charles A. Lindbergh Visiting Professor of Aerospace History at the National Air and Space Museum. He has flown in a wide range of tactical aircraft and has written 13 books on aerospace history.

The Legacy of the Lifting Body. Stephan Wilkinson is a contributing editor of *Air & Space/Smithsonian.* His last article was "Mach 1: Assaulting the Barrier" (December 1990/January 1991).

Rally 'Round the Pharaohs. Anna Maryke is a freelance writer who has worked primarily for Australian publications. She travels the globe in search of unusual and adrenaline-pumping activities.

Freelance photographer Simon Chaput started hang gliding in 1976. He flew and crashed his first ultralight in 1982.

How to Succeed in Business Without Really Flying. Frank Kuznik is a Washington, D.C.-based freelance writer.

The Height of Ambition. David H. DeVorkin is curator of astronomy and space sciences at the National Air and Space Museum's department of space history.

Divine Inspiration. Richard Sassaman, who believes that God intended man to fly, lives in Bar Harbor, Maine. This is his third appearance in *Air & Space/Smithsonian.*

Model Behavior. Linda Shiner is senior editor at *Air & Space/Smithsonian.*

"The Satellite Sky" Update/23

These regular updates to **"The Satellite Sky"** chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

Deletions

90 to 300 MILES

Cosmos 1686
down 2-7-91

Cosmos 2102
down 12-12-90

Cosmos 2108
down 1-28-91

Salyut 7
down 2-7-91

Soyuz TM-10
down 12-10-90

Launched but not in orbit

90 to 300 MILES

Cosmos 2120 USSR photo recon	12-26-90	down 1-17-91

Inoperative but still in orbit

300 to 630 MILES

Cosmos 1992

21,750 to 22,370 MILES

Ekran 18

Superbird A

New launches

90 to 300 MILES

Cosmos 2113
12-21-90 TT

Cosmos 2121
1-17-91 PL

Cosmos 2122
1-18-91 TT

Cosmos 2124
2-7-91 PL

Progress M-6
1-14-91 TT

300 to 630 MILES

Cosmos 2112
12-10-90 PL

Cosmos 2123
2-5-91 PL

Informator-1
1-29-91 PL

630 to 1,250 MILES

Cosmos 2114-19
12-22-90 PL

6,200 to 13,700 MILES

Cosmos 2109-11
12-8-90 TT

21,750 to 22,370 MILES

Eutelsat-2F2
1-15-91 KOU

Italsat-1
1-15-91 KOU

NATO 4A
1-8-91 CAC

Raduga 26
12-20-90 TT

Raduga 1-2
12-27-90 TT

Forecast

In the Wings...

Jimmie Angel. He's remembered for landing cargo planes almost anywhere and for the Venezuelan waterfall that bears his name. But if this pilot had had his way, he'd be known for a fortune in gold.

Mars Rovers. A look at the challenges of making the ultimate off-road vehicle.

Custom-Made Pilots. The flight training is called *ab initio*—"from the beginning"—and foreign airlines have used it for years to turn non-pilots into pilots. Will an evaporating pool of seasoned pilots force U.S. airlines to take the same course?

BILL CRUMP

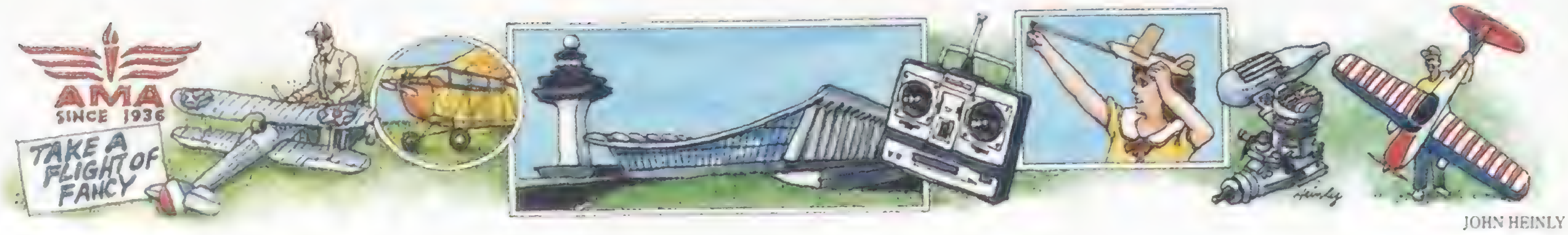
How to Fly a P-51. As a cadet, Ron Dick wanted to fly a Mustang. Nearly four decades later, that dream finally came true.

Stormy Weather. The sun always shines on the weather forecasters at the Space Environment Services Center, who predict and monitor solar and geomagnetic storms.

Airplane Camouflage. In wartime flying, sometimes you need to hide and sometimes you need to be seen. It's a conflict as old as war itself.

Son of Shuttle. Though NASA doesn't like to admit it, the space shuttle can't go on forever. Here's a look at the designs already being proposed for the next generation of shuttlecraft.

Collections



JOHN HEINLY

Model Behavior

Your first clue that the Academy of Model Aeronautics headquarters is as much a sports hall of fame as an aviation museum is in the parking lot, where a van parked near the glass doors carries an AMA logo with the boast "The World's Largest Sport Aviation Organization." Inside, among a swarm of some of the world's smallest airplanes—suspended on wires, housed in glass cases, bristling from poles—are all the trappings of competition: ribbons, medals, trophies, and photographs from the winners' circle.

Out past Northern Virginia's ugly postmodern high-rise eruption, in a low-rise professional park near Washington-Dulles International Airport, the AMA headquarters blends in with its brown brick neighbors. The National Grocers Association is across the street; a science center is on the corner; banks and fast food franchises cluster nearby. Nowhere in evidence are the wide-open spaces that fliers of model airplanes crave, and that's why the AMA recently bought 950 acres in Muncie, Indiana, where it plans to build a national flying site. Middletown USA, as Muncie has been called, seems a more suitable location for AMA functions, which share certain values with the heartland. (Surely there must be an episode of "Father Knows Best" in which Bud builds a flying model airplane and is rewarded for his hard work and patience with good, clean fun.)

Some of the free-flight gliders and radio-controlled endurance models among the museum's 600 aircraft predate the academy, which was founded in 1936. The collection also represents many of the 84 categories of competition that the organization sanctions in about 2,600 events every year. One prominently displayed model is a radio-controlled pylon racer, weighing about five pounds with a 4.5-foot wingspan, that took first place for the United States in an international race held in Australia in 1988. Shinier—and faster—than a new Porsche, the cherry red speedster flew 10 furious laps around a triangular course at more than 200 mph to win the medal.

Nearby a lone combat airplane exudes none of the racer's glamour, although combat is another event in which speed counts. Combat with models is a kind of dogfight in which control-line models—one-cylinder-engine airplanes flown on lines attached to a control handle—chase one another around a circle. Holding onto the handles in the center, the pilots use the propellers to cut paper streamers attached to the tails of their opponents' airplanes. Sure enough, the little dogfighter on the shelf trailed a pair of ignominiously tattered streamers, proof of its bravery if not its speed.

Not all of the models in the collection are competitors; some only look like it. The gleaming metalwork on one non-flying scale model, a tiny Curtiss P6E Hawk Army Air Corps fighter, would be right at home in a glass case at Tiffany's. Builders of static models focus on realistic reproduction of historic aircraft, with beauty often the by-product. (Important etiquette tip: When discussing scale models with a modeler, be sure to refer to the original craft as "full scale" not "real." To a modeler, an airplane is an airplane, no matter how small.)

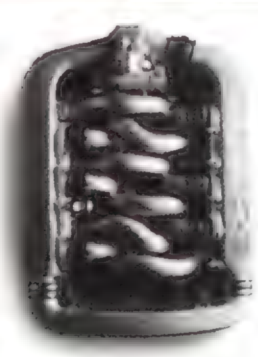
If you want to visit the AMA, try to come on one of the days Hurst Bowers is there. Bowers, a retired Air Force colonel who works as the museum curator several days a week, is a light-hearted raconteur from Georgia who has been building models since he was six. "When I was a little kid I had a cousin who had infantile paralysis—polio, I guess they called it later," Bowers told me. "He couldn't do anything else, so he sat on the front porch and built models. He was kind and patient and taught me to build models, and I kept on until high school, and then I gave it up. I went to college, and the war came along. After the war I found myself on an island in one of the Azores group, and regardless of how hard I tried, the Portuguese could make wine faster than I could drink it, so I conceded and went back to modeling. Best thing I ever did."

One of Bowers' favorite stories concerns the enormous model of a Bellanca Skyrocket hanging on a wall. Roland Spicer, an AMA member in his 80s, built the radio-controlled Skyrocket, which weighs about 100 pounds, outfitted it with a Japanese chainsaw engine, and then got an idea. In 1982, after gaining permission from the Federal Aviation Administration, Spicer filled the Skyrocket's tank with 6.5 gallons of fuel, hopped into his car with a couple of friends, and launched the airplane. The three then gave chase to the Skyrocket, which Spicer flew over the median strips of Florida's highways nonstop from the St. Augustine airport to Jacksonville, Tallahassee, and back to St. Augustine. A technicality kept Spicer from claiming an official distance record, but Bowers finds it greatly amusing to imagine how exhausted the members of the ground crew must have been when they finally rolled to a stop back at St. Augustine after roaring around Florida at 60 mph for seven hours.

Of course models aren't just for fun. Aircraft designers since the Wright brothers have used scale models to test their theories of aerodynamics and have saved untold sums by thinking big but first building small. A 24-inch scale model of the space shuttle *Enterprise* perched atop a 1:40 scale Boeing 747 in the center of the museum demonstrates the serious side of building models. Constructed by two engineers at NASA's Manned Spacecraft Center in Houston, the pair of radio-controlled aircraft tested a miniature version of the release mechanism that enabled the prototype shuttle to separate from its carrier. The engineers performed several tests in which the mated models flew, separated, and landed successfully. In the photographs the engineers appear to be typical model builders: hard at work and loving every minute of it.

—Linda Shiner

Academy of Model Aeronautics, 1810 Samuel Morse Drive, Reston, VA 22090. Tel. (703) 435-0750. Open weekdays 9 a.m. to 5 p.m., Saturday 10 a.m. to 3 p.m. Admission free. Reservations recommended for large groups.



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220 HP
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Executive conference room.

When your career's on the fast track, you need a car that belongs there. The Taurus SHO. Its distinctive appointments include fully-articulated sport seats (leather trim optional) and performance instrumentation. The Taurus SHO is perfect for a closed conference, even if your only meeting is with the available JBL stereo and your favorite compact disc.

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Rounding out Taurus SHO's portfolio are a special sports suspension, 4-wheel disc anti-lock brakes, and standard driver's side air bag supplemental restraint system to be used with your safety belt. And with new 16″ cast aluminum wheels, the SHO will quickly improve your outlook.

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Ford Taurus SHO

Buckle up—together we can save lives.

Have you driven a Ford...lately?

10 Years of Space Shuttles

A special birthday poster to commemorate the Space Transportation System's first decade of operation

AIR&SPACE
Smithsonian

A supplement to the April/May 1991 issue of *Air & Space/Smithsonian* magazine

"THE PRESENT CONTAINS NOTHING MORE THAN THE PAST, AND WHAT IS FOUND IN THE EFFECT WAS ALREADY IN THE CAUSE."

Henri Bergson

ONE LOOK AT AUDI'S PAST TELLS YOU WHY THE V8 QUATTRO IS THE CAR OF THE FUTURE.

If one expects their creations to have any lasting effect on history, an individual must have the courage to take control of destiny and follow their visions on a clear undaunted course. And so it was in 1899, when Dr. August Horch (rhymes with "torque"), founded A. Horch & Cie., a tiny automaking company in Cologne, Germany.

AERODYNAMIC BEGINNINGS

Horch was one of the first car builders to understand that an automobile must swim through an ocean of air. He believed that effective airflow management could lead to greater speeds and better control. All this at a time before most car makers even knew what aerodynamics was. Unfortunately, Horch's financial backers lacked his confidence and vision, and in 1909 they withdrew their support.

AUDI IS BORN

Undaunted, Horch boldly founded a new company less than a year later, naming it after the Latin translation of his name: *Audi.* He readily applied his theories of airflow management to his 1911 Alpensieger (Alps Conqueror).

1911 Alpensieger

He proved his theories on the race course, piloting the Alpensieger to three consecutive Alpine Rally victories. The years ahead were full of exciting automotive innovation.

In 1931, Audi's soon-to-be-partner, DKW, pioneered the world's first front-wheel drive car. A year later, Audi consolidated with Horch, Wanderer and DKW, forming Auto Union, and adopted their current symbol of four linked rings. From 1934-38, Audi's Grand Prix race cars dominated racing, attaining speeds exceeding 200 mph. Again, Horch's visionary concepts in aerodynamics led Audi's engineers to go beyond basic streamlining to apply such advanced concepts as ground effects and wheel turbulence reduction for an added measure of control.

A SUCCESSION OF FIRSTS

As speed and engine power increased, so did the need for driver control. And by 1955, the engineers at Audi began testing

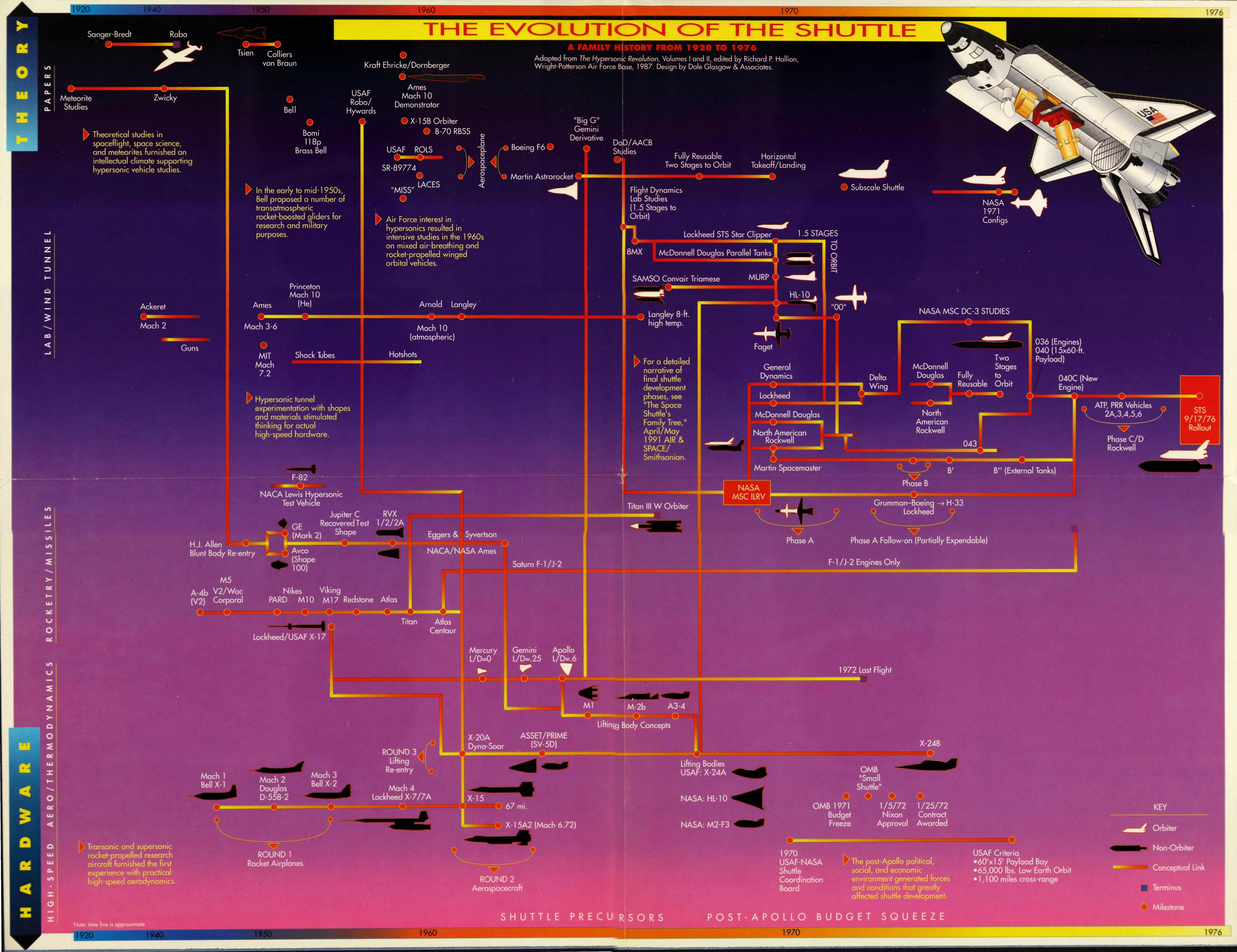
TAKE CONTROL

the viability of permanent all-wheel drive. The results were astounding, and in 1977 a prototype Audi Quattro® climbed a snow-bound winter pass with a 20 degree incline — on summer tires. They transferred this technology to the new Audi Quattro which made its first public appearance at the Geneva Salon in March of 1980. Two years later, Horch's ultimate vision was achieved. The Audi 100's aerodynamic styling produced a .30 drag coefficient, setting a new world record and paving the way for an industry-wide trend in aerodynamic design. In 1986, Audi introduced the 5000CS Turbo Quattro, the first Audi to feature Anti-Lock Brakes, setting the stage for the Audis that were to come.

THE 1991 V8 QUATTRO

The world's first fully-automatic Quattro all-wheel drive. A car that translates 90 years of unconventional automotive thinking into a powerful yet controlled driving experience. Featuring a powerful 32-valve, V8 engine. A Quattro all-wheel drive system that uses ABS sensors to continually monitor traction in all four wheels. And the luxury of a voice-activated car phone and a Bose® premium music system. You might say it's the car of the future. But we prefer to think of it as the logical conclusion to years of automotive innovation. The rest is history.

Audi V8 Quattro


THE EVOLUTION OF THE SHUTTLE
A FAMILY HISTORY FROM 1920 TO 1976
Adapted from The Hypersonic Revolution, Volumes I and II, edited by Richard P. Hallion, Wright-Patterson Air Force Base, 1987. Design by Dale Glasgow & Associates.
1920
1940
1950
1960
1970
1976
THEORY
PAPERS
LAB/WIND TUNNEL
HARDWARE
ROCKETRY/MISSILES
AERO/THERMODYNAMICS
HIGH-SPEED
Sanger-Bredt
Rabo
Tsien
Colliers von Braun
Kraft Ehricke/Dornberger
Meteorite Studies
Zwicky
Bell
USAF Robo/ Hywards
Ames Mach 10 Demonstrator
X-15B Orbiter
B-70 RBSS
Bomi 118p Brass Bell
USAF
ROLS
SR-89774
LACES
"MISS"
Aerospaceplane
Boeing F6
Martin Astrorocket
"Big G" Gemini Derivative
DoD/AACB Studies
Fully Reusable Two Stages to Orbit
Horizontal Takeoff/Landing
Subscale Shuttle
NASA 1971 Configs
Theoretical studies in spaceflight, space science, and meteorites furnished an intellectual climate supporting hypersonic vehicle studies.
In the early to mid-1950s, Bell proposed a number of transatmospheric rocket-boosted gliders for research and military purposes.
Air Force interest in hypersonics resulted in intensive studies in the 1960s on mixed air-breathing and rocket-propelled winged orbital vehicles.
Flight Dynamics Lab Studies (1.5 Stages to Orbit)
Lockheed STS Star Clipper
1.5 STAGES TO ORBIT
8MX
McDonnell Douglas Parallel Tanks
SAMSO Convair Triamese
MURP
HL-10
"00"
Ackeret
Mach 2
Guns
Ames
Mach 3-6
Princeton Mach 10 (He)
Arnold
Langley
Mach 10 (atmospheric)
Langley 8-ft. high temp.
Faget
NASA MSC DC-3 STUDIES
MIT Mach 7.2
Shock Tubes
Hotshots
For a detailed narrative of final shuttle development phases, see "The Space Shuttle's Family Tree," April/May 1991 AIR & SPACE/ Smithsonian.
General Dynamics
Lockheed
McDonnell Douglas
North American Rockwell
Martin Spacemaster
Delta Wing
McDonnell Douglas
North American Rockwell
Fully Reusable
Two Stages to Orbit
036 (Engines)
040 (15x60-ft. Payload)
040C (New Engine)
043
ATP, PRR Vehicles 2A,3,4,5,6
Phase C/D Rockwell
STS 9/17/76 Rollout
B'
B'' (External Tanks)
Phase B
Hypersonic tunnel experimentation with shapes and materials stimulated thinking for actual high-speed hardware.
F-82
NACA Lewis Hypersonic Test Vehicle
NASA MSC ILRV
Titan III W Orbiter
Grumman-Boeing → H-33 Lockheed
Phase A
Phase A Follow-on (Partially Expendable)
H.J. Allen Blunt Body Re-entry
GE (Mark 2)
Avco (Shape 100)
Jupiter C Recovered Test Shape
RVX 1/2/2A
Eggers & Syvertson
NACA/NASA Ames
Saturn F-1/J-2
F-1/J-2 Engines Only
A-4b (V2)
M5 V2/Wac Corporal
Nikes PARD
M10
Viking M17
Redstone
Atlas
Titan
Atlas Centaur
Lockheed/USAF X-17
Mercury L/D=0
Gemini L/D=.25
Apollo L/D=.6
1972 Last Flight
M1
M-2b
A3-4
Lifting Body Concepts
ROUND 3 Lifting Re-entry
X-20A Dyna-Soar
ASSET/PRIME (SV-5D)
X-24B
Lifting Bodies USAF: X-24A
NASA: HL-10
NASA: M2-F3
OMB "Small Shuttle"
OMB 1971 Budget Freeze
1/5/72 Nixon Approval
1/25/72 Contract Awarded
Mach 1 Bell X-1
Mach 2 Douglas D-558-2
Mach 3 Bell X-2
Mach 4 Lockheed X-7/7A
X-15
67 mi.
X-15A2 (Mach 6.72)
ROUND 1 Rocket Airplanes
ROUND 2 Aerospacecraft
Transonic and supersonic rocket-propelled research aircraft furnished the first experience with practical high-speed aerodynamics.
1970 USAF-NASA Shuttle Coordination Board
The post-Apollo political, social, and economic environment generated forces and conditions that greatly affected shuttle development.
USAF Criteria
•60'x15' Payload Bay
•65,000 lbs. Low Earth Orbit
•1,100 miles cross-range
KEY
Orbiter
Non-Orbiter
Conceptual Link
Terminus
Milestone
USA
SHUTTLE PRECURSORS
POST-APOLLO BUDGET SQUEEZE
Note: time line is approximate

Pierre Mion
Carter Emmart
Dave Pwerle Ross
Andrei Sokolov
Vitaly Myagkov
Brian Sullivan

Mark Strauss
Beth Avary
Harriet Cortez
Toni Littlejohn/Allesondra Springmann
David Fricks
William Palmstrom

Ken Dallison
Alan Cober
Tibor Toth
Tina Mion
David Clark
Michael Rodericks

Stan Stokes
Pamela Lee
Dale Glasgow
Michael Carroll

Barbara Huston
Paul Salmon
Robert McCall
Mark Hamel
Douglas Edwards
Leslie Cober

India Watkins
George Guzzi
Stephan Hickman
Web Bryant
Kovalev/Kovaleva
Ruth Duckett

Rebecca George
Albert Slink
Dennis Davidson
Stanley George
Paul DiMare
Kara Szathmary

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Snap rolls, hammerheads, Cuban eights . . . these daring and intricate airborne maneuvers are just part of the Eagles Aerobatic Flight Team's vast repertoire. Flying wingtip-to-wingtip at speeds of 200 mph, often only six feet off the deck, the Eagles must perform with split-second timing. These gifted pilots wear the timepiece they can trust: The Rolex GMT-Master II Oyster Perpetual Date with an independent 24-hour hand and bezel. Available in stainless steel, 18 kt. gold or a combination of steel and gold . . . It's your timepiece of choice when timing is critical.
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